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AGRICULTURAL MATERIALS HANDLING MANUAL

PART 2 CONVEYORS

SECTION 2.3

AUGER AND BUCKET CONVEYORS

Agriculture
Canada

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SECTION 2.3

AUGER AND BUCKET CONVEYORS

The Agricultural Materials Handling Manual is produced in several parts as a guide to designers of materials handling systems for farms and associated industries. Sections deal with selection and design of specific types of equipment for materials handling and processing. Items may be required to function independently or as components of a system. The design of a complete system may require information from several sections of the manual.

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SYMBOLS

- a - cross sectional area (m^2)
- b - bulk density (kg/m^3)
- C - capacity m^3
- c - coefficient of loading
- d - diameter (m)
- e - efficiency
- F_c - centrifugal force (N)
- F_e - force to move empty conveyor (N)
- g - acceleration of gravity (9.81 m/s^2)
- H - elevation change or height (m)
- k - loading factor for augers
- L - length of conveyor (m)
- L_c - assumed extra length of conveyor to compensate for friction
- M - mass of material
- M_m - mass of material conveyed (kg)
- M_p - mass of sliding parts of conveyor (kg)
- n - rpm or rps
- P - power (W)
- P_e - power for driving empty conveyor (W)
- P_m - power for moving material conveyed (W)
- P_r - power for elevating material (W)
- R - effective radius of center of rotation (m)
- S - spacing (m)
- T - capacity of conveyor (kg/s)
- v - volume (m^3)
- V - velocity (m/s)
- w - width of conveyor (m)
- μ - tangent of angle of repose
- μ_m - coefficient of friction between material and conveyor
- μ_p - coefficient of friction between flights on bottom of conveyor

SECTION 2.3 AUGER AND BUCKET CONVEYORS

2.3.1 AUGER CONVEYORS

The auger or screw conveyor consists of a revolving screw in a suitably shaped stationary trough or casing fitted with hangars, trough ends and other auxiliary accessories. The auger conveyor is an adaptation of the Archimedian screw pump and thus has a classical background.

Auger conveyors are compact, easily adapted to congested locations and can be mounted horizontally, inclined or vertically. They can be used to control the flow of material in processing operations such as mixing, stirring or agitating. They are widely used in agriculture to feed combines, hay balers and forage blowers and for feed bunks and grain conveyors. Where abrasive materials are to be handled, hard surfacing of the screw is advisable. For handling sticky materials ribbon type flighting should be used. This arrangement leaves a clear space between the central shaft and the screw and helps to eliminate the build-up of material along the shaft.

The helix of inclined screw conveyors is usually enclosed by a metal tube with the clearance between the flighting and tube reduced to a minimum. The loading factor, or ratio of the volume of material in the tube to the tube volume, varies from 0.15 for very dry low-cohesion materials like dry sand or dust to 0.75 for enclosed conveyors with medium or high cohesion materials. The 0.75 essentially allows for the space occupied by the helix and the shaft.

The intake and discharge methods vary widely. They can be fed from other conveyors or placed directly in the base of a bin. Discharge points can be anywhere along the bottom of the auger such as a continuous slot as in the case of feed bunks or through a single spout at the head end as in portable grain augers. They are particularly adaptable to situations where the supply is not uniform (i.e. surges) and will deliver the material at a uniform rate governed by the speed of rotation of the screw. The auger conveyor can also be started or stopped while fully loaded with material.

2.3.1.1 **Descriptive Data**

Helicoidal Flight Conveyor Screws

The helix is a smooth, continuous one-piece flight, formed from flat steel sheet mounted on a pipe or shaft. The rolling process effects a hardening and smoothing of the flight surface which increases resistance to wear and reduces friction and power requirements. The pipe is selected for adequate torsional strength and resistance to excessive deflection.

Helicoid flight conveyor screws are interchangeable with sectional flight conveyor screws of the same diameter and shaft size.

Heliocoidal flighting is made in regular pitch which is approximately equal to the diameter. It can also be made in other than regular pitch and in a wide variety of thicknesses, diameters and lengths to meet some requirements.

Sectional Flight Conveyor Screws

Sectional flight conveyor screws are made of individual flights, formed into a helix from flat steel plate and butt welded or riveted together.

Section flights afford flexibility in choice of diameter, pitch and thicknesses. They are also interchangeable with helicoid flight conveyor screws of the same specifications.

Quick Link Conveyor Screws

This conveyor screw is designed for easy removal from the conveyor trough. Each section of screw is equipped with a removable key for disassembly without disturbing other components. These conveyor screws are available in both helicoid and sectional flight construction.

Cut Flight Conveyor Screws

Notches cut in the periphery of either helicoid or sectional flights supplement the conveying action with a moderate amount of mixing action. These screws are used for light, fine, granular or flaky material.

Cut and Folded Flight Conveyor Screws

Folded segments around the periphery of the flights provide a lifting and cascading action. The resulting agitation and aeration provide better mixing. These screws are used for light to medium weight, fine, granular or flaky materials.

Cut Flight Conveyor Screws with Paddles

Paddles mounted at intervals are set to counteract the flow of material thus considerably increasing the agitation and mixing action produced by cut flights.

Conveyor Screws with Paddles

Adjustable paddles spaced at intervals and set to partially oppose the flow, produce a moderate mixing action of conveyed material. The paddles are adjustable to give the desired degree of agitation for light to medium weight, fine, granular or flaky materials.

Short Pitch Conveyor Screws

The pitch of these screws is reduced for use in inclined and vertical conveyors and for use as feeder screws. They also retard flushing of granular materials.

Ribbon Flight Conveyor Screws

Steel bars formed into a continuous helical flight are attached to the central pipe with supporting lugs. These conveyors are used in horizontal feed mixers, and for conveying sticky, gummy or viscous substances and where material tends to adhere to the flighting at its junction with the pipe.

Paddle Conveyor Screws

Formed steel blades are mounted to the pipe with shanks that provide for adjusting the angle of the paddles. These conveyors are used for mixing, blending or stirring dry or fluid materials with molasses.

Stainless Steel Conveyor Screws

These units are suited to sanitation requirements for food, chemical and allied products for resistance to corrosion and for application of moderate to extreme heat.

Tapered Flight Conveyor Screws

Tapered conveyor screws are used as feeder screws for handling friable lumpy material from bins and hoppers and also to draw materials uniformly from the entire length of the feed opening.

Stepped Diameter Screws

Flights of different diameters and each with regular pitch are mounted in tandem on one shaft. They are used as feeder screws with the smaller diameter located under the bin or hopper to regulate the flow of materials.

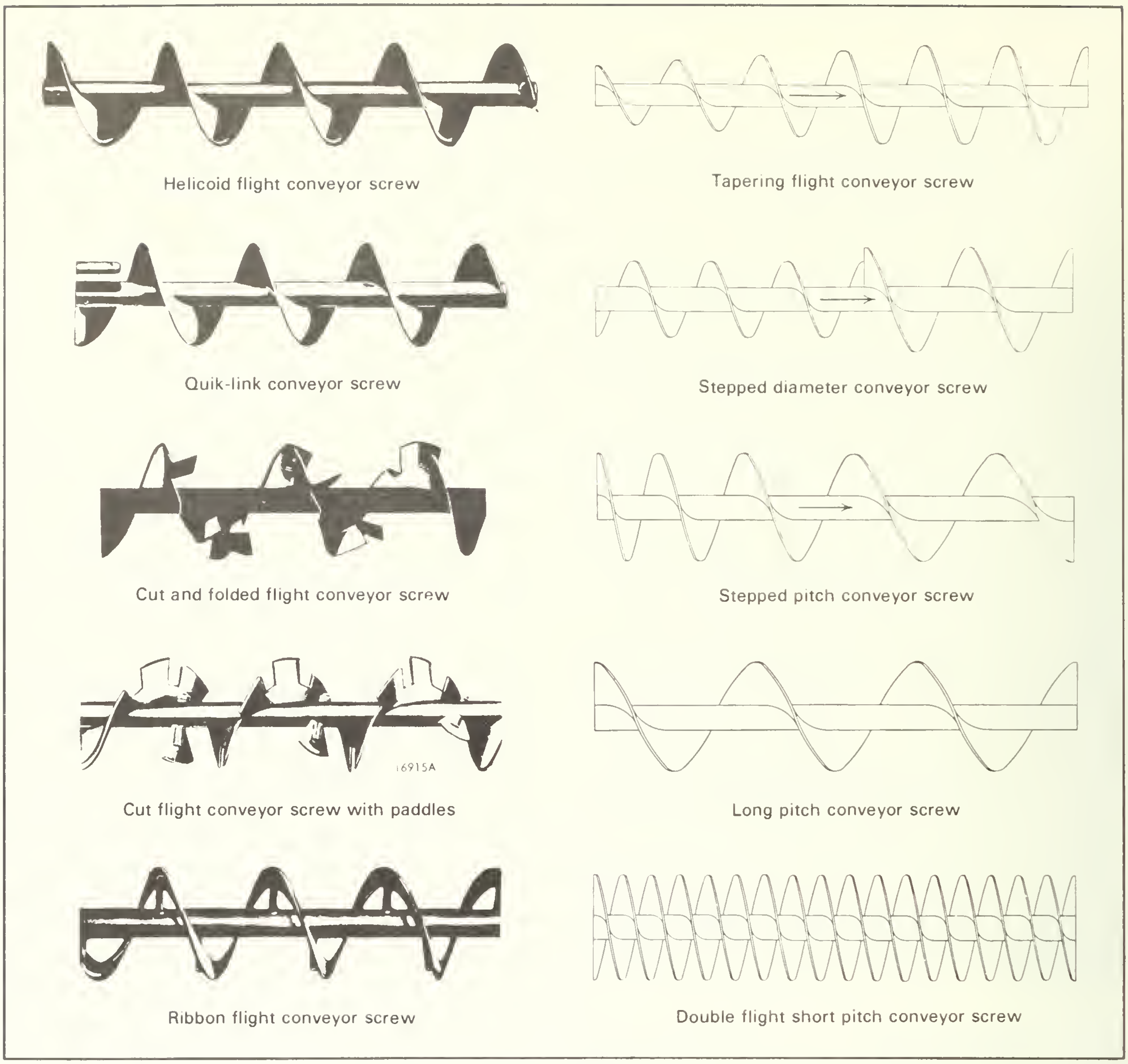


Figure 2.3.1 Examples of conveyor screws (adapted from Link-belt Screw Conveyors and Screw Feeders - FMC.)

Stepped Pitch Conveyor Screws

Succeeding single or groups of sectional flights increasing in pitch are used as feeder screws to draw fine free flowing materials uniformly from the entire length of the feed opening.

Long Pitch Conveyor Screws

These screws can be used as agitators for liquids or for rapid conveying of free flowing materials.

Double Flight Conveyor Screws

The flights have regular pitch and promote smooth gentle flow of certain materials.

Double Flight Short Pitch Screws

When accurate regulation of feed and flow in screw feeders is required these screws are particularly effective.

2.3.1.2 **Capacity**

The speed of rotation varies from 200-300 rpm for 300 mm (12 in.) diameter to 900 to 1000 rpm for 100 mm (4 in.) diameter augers.

The pitch or distance along the auger between two similar points on the helix is usually equal to the diameter of the screw. Therefore the velocity of material along the length of the conveyor can be determined from:

$$V = n\,d \qquad [1]$$

where V = velocity (m/s)

n = revolution per second

d = diameter (m)

The capacity of an auger conveyor can be calculated from the equation:

$$T = \frac{k \pi d^3 nb}{4} \quad [2]$$

where T = capacity (kg/s)

b = bulk density (kg/m^3)

K = loading factor (Table 2.3.1)

n and d are defined in equation [1]

The loading factor "k" for enclosed augers at an incline or vertical will be a maximum of 0.75 to allow for space occupied by the helix and shaft. Thus the capacity of inclined augers can be estimated however, depending on the clearance between the helix and inside of the tube this estimate may be high. The back pressure of the conveyed material on the helix will determine the torque required to drive the auger and so power calculations are very difficult. Therefore, one must usually rely on manufacturers' recommendations or experimental evidence to determine the size of power unit required.

2.3.1.3 Power Requirements

To calculate the power required for horizontal installations it is recommended that the theoretical power be multiplied by 3 to allow for friction of the helix, bearing friction etc. and that an efficiency of .75 be used for the drive train (3). The friction forces set up in the moving mass of material are complex but there is likely to be some material adhere to the helix and to the trough therefore, for cohesive materials the interparticle friction of the material will predominate and should be used in calculations. For non-cohesive materials the angle of repose can be used. Brooks (3) states that an estimate of power requirements can be calculated from:

$$P = \frac{3 T g L \mu}{e} \quad [3]$$

Where P = power (W)

T = capacity (kg/s)

g = acceleration of gravity (9.8 m/s^2)

L = conveyor length (m)

μ tangent of angle of repose

e = efficiency

2.3.1.4 Example Problem

A 250 mm (10 in.) diameter horizontal auger conveyor 30 m (100 ft) long is to handle wheat at the rate of 87 m^3 per hour (2400 bu per hr). Choose a suitable electric drive motor.

Taking the density of wheat as 769 kg/m^3 (48 lb/ft^3) and angle of repose 26°, therefore $\mu = \tan 26°$ (Table 7.1.24), then:

$$T = 87(769)/3600$$
$$= 18.6 \text{ kg/s}$$

therefore, the power required is:

$$P = \frac{3 T g L \tan 26°}{e}$$
$$= \frac{3(18.6)(9.81)(30)(.487)}{.75}$$
$$= 10.7 \text{ kW or } 14.3 \text{ hp}$$

Therefore, choose a 15 hp motor.

Table 2.3.1 Loading Factors "k" for Horizontal Conveyors

Material	k	Material	k
Alfalfa meal	0.30	Lime hydrated	0.30
Barley	0.45	Limestone agricultural	0.30
Beans	0.45	Malt	0.30
Bean meal	0.30	Milk powdered	0.30
Bone meal	0.30	Mustard seed	0.45
Bran	0.30	Oats	0.45
Brewers grain spent dry	0.30	Oats rolled	0.30
Buckwheat	0.45	Oyster shell ground	0.30
Clover seed	0.45	Peas dried	0.45
Corn cracked	0.30	Rice rough	0.30
Corn shelled	0.45	Rye	0.45
Fish meal	0.30	Sawdust - consult conveyor manufacturer	
Grains distillery spent	0.30	Wheat	0.45
Grass seed	0.30	Wheat cracked	0.30
Hops	0.30	Wood chips	0.30

2.3.1.5 Auger Conveyor Specifications

Power requirements and other auger conveyor specifications may be more easily obtained from the following tables when the material being handled has characteristics similar to dry grains. These include barley, bran, brewers grain, shelled corn, corn germ, corn meal, cottonseed meal, malt, maize, oats, rice, rye, soybeans, timothy, wheat and cracked wheat.

Tables 2.3.2, 2.3.3 and 2.3.6 to 2.3.8 inclusive are based on data in Research Bulletin No. 740, Purdue University Agricultural Experiment Station (8). The power listed is that required at the drive shaft and a further 10% should be added to the tabulated values to obtain the total watts or horsepower requirement. To estimate capacities between tabulated values, note that capacity decreases as angle of incline increases.

Power requirements for commercial portable augers set to elevate dry grain at an angle of 40° to 45° are listed in Table 2.3.11. Table 2.3.12 shows electric motor sizes recommended for horizontal and vertical distributing augers.

TABLE 2.3.2 100 mm (4 in.) Auger Conveyor Handling Dry Shelled Corn*

Auger Speed	Length of Exposed Helix at Intake	Angle of Elevation					
		0°		45°		90°	
rpm	mm	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m
200	150	5.1	26.9	4.0	31.8	1.5	24.5
	300	5.5	29.4	4.4	36.7	2.2	26.9
	460	5.5	31.8	4.4	41.6	2.5	29.4
	610	5.5	34.3	4.4	44.0	2.9	31.8
400	150	9.8	56.3	6.5	61.1	3.3	46.5
	300	10.5	70.9	8.0	70.9	4.7	46.5
	460	10.5	80.7	8.7	78.3	5.5	63.6
	610	10.9	93.0	8.7	88.1	5.8	66.1
700	150	14.9	80.7	10.2	97.9	5.8	70.9
	300	17.1	105.2	12.7	127.2	8.0	100.3
	460	17.5	124.8	13.8	156.6	9.1	115.0
	610	17.5	146.8	13.8	185.9	9.8	119.9
1180	150	17.8	100.3	11.6	149.2	7.3	112.5
	300	23.6	154.1	16.7	198.2	11.3	163.9
	460	26.9	207.9	19.3	247.1	13.1	193.3
	610	28.0	264.2	20.4	296.0	13.8	215.3

Auger Speed	Length of Exposed Helix at Intake	Angle of Elevation					
		0°		45°		90°	
rpm	in	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′
200	6	140	.11	110	.13	40	.10
	12	150	.12	120	.15	60	.11
	18	150	.13	120	.17	70	.12
	24	150	.14	120	.18	80	.13
400	6	270	.23	180	.25	90	.19
	12	290	.29	220	.29	130	.24
	18	290	.33	240	.32	150	.26
	24	200	.38	240	.36	160	.27
700	6	410	.33	280	.40	160	.29
	12	470	.43	350	.52	220	.41
	18	480	.51	380	.64	250	.47
	24	480	.60	380	.76	270	.49
1180	6	490	.41	320	.61	200	.46
	12	650	.63	460	.81	310	.67
	18	740	.85	530	1.01	360	.79
	24	770	1.08	560	1.21	380	.88

*Grain density 675-700 kg/m^3 (54 to 56 lb/ft^3); 13.2 to 14% wet basis.

TABLE 2.3.3 100 mm (4 in.) Auger Conveyor Handling Dry Soybeans*

Auger Speed	Intake Exposure	Angle of Elevation									
		0°		22.5°		45°		67.5°		90°	
rpm	mm	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m
	150	7.4	36.7	6.3	51.4	5.3	53.8	3.5	41.6	2.8	41.6
	300	7.6	39.1	6.7	53.8	5.6	58.7	4.9	56.3	3.9	46.5
300	460	7.8	51.4	6.7	61.2	5.6	63.6	5.3	61.2	4.2	51.4
	610	7.8	51.4	6.7	63.6	6.0	66.1	5.3	63.6	4.6	58.7
	150	11.6	56.3	9.7	75.8	8.1	63.2	6.0	78.3	4.6	66.1
	300	12.0	66.1	10.6	95.4	9.2	105.2	7.0	97.9	5.6	80.7
500	460	12.3	85.6	10.9	100.1	9.5	115.0	8.1	105.2	6.3	85.6
	610	12.7	93.0	10.9	117.4	9.7	119.9	8.8	112.5	7.8	100.3
	150	14.8	68.5	12.7	100.3	10.2	110.1	7.4	100.3	6.0	90.5
	300	15.9	90.5	14.1	132.1	12.3	146.8	9.5	139.5	7.4	115.0
700	460	16.6	120.0	14.4	154.1	13.4	161.5	10.2	146.8	8.5	119.9
	610	17.6	130.0	15.3	161.5	13.4	173.7	11.6	159.0	10.2	141.9
	150	16.4	80.7	14.1	119.9	11.6	134.6	8.5	124.8	7.0	110.1
	300	18.3	115.0	16.6	163.9	14.4	181.0	10.9	173.7	8.8	146.8
900	460	20.0	151.7	18.3	198.2	16.2	207.9	12.3	188.4	10.6	154.1
	610	22.6	168.8	19.3	212.8	16.6	227.5	14.1	205.5	12.3	178.6
	150	17.3	93.0	14.8	137.0	12.0	156.6	9.3	146.8	7.8	134.6
	300	21.1	134.6	18.7	190.8	16.2	210.4	11.3	200.6	9.7	173.7
1100	460	24.3	188.4	21.5	244.6	18.7	252.0	13.7	225.1	12.0	298.2
	610	27.5	205.5	22.9	259.3	19.0	278.9	15.9	247.1	14.1	225.1

Auger Speed	Intake Exposure	Angle of Elevation									
		0°		22.5°		45°		67.5°		90°	
rpm	in	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′
	6	210	.15	180	.21	150	.22	100	.17	80	.17
	12	215	.16	190	.22	160	.24	140	.23	110	.19
300	18	220	.21	190	.25	160	.26	150	.25	120	.21
	24	220	.21	190	.26	170	.27	150	.26	130	.24
	6	330	.23	280	.31	230	.34	170	.32	130	.27
	12	340	.27	300	.39	260	.43	200	.40	160	.33
500	18	350	.35	310	.45	270	.47	230	.43	180	.35
	24	360	.38	310	.48	280	.49	250	.46	220	.41
	6	420	.28	360	.41	290	.45	210	.41	170	.37
	12	450	.37	400	.54	350	.60	270	.57	210	.37
700	18	470	.49	410	.63	380	.66	290	.60	240	.49
	24	500	.53	435	.66	380	.71	330	.65	390	.58
	6	456	.33	400	.49	330	.55	240	.51	200	.45
	12	520	.47	470	.67	410	.74	310	.71	250	.60
900	18	570	.62	520	.81	460	.85	350	.77	300	.63
	24	640	.69	550	.87	470	.93	400	.84	350	.73
	6	490	.38	420	.56	340	.64	265	.60	220	.55
	12	600	.55	530	.78	460	.86	320	.82	280	.71
1100	18	690	.77	610	1.00	530	1.03	390	.92	340	.81
	24	780	.84	650	1.06	540	1.14	450	1.01	400	.92

*Grain density 675-700 kg/m^3 (54 to 56 lb/ft^3); 13.2 to 14% wet basis.

TABLE 2.3.4 100 mm (4 in.) Auger Conveyor Handling Wheat* With 150 mm (6 in.) Exposed Helix at Intake

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m
300	7.3	53.8	6.2	61.2	4.7	61.2	2.5	46.5
400	9.5	68.5	8.0	78.3	6.5	73.4	3.3	61.2
600	13.8	88.1	11.3	107.6	8.4	110.1	4.7	88.1
800	15.6	97.9	12.7	127.2	10.5	139.4	6.2	112.5
1000	17.1	105.2	13.8	144.3	11.3	168.5	6.9	134.6

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	bu/hr	hp/10'	bu/hr	hp/10'	bu/hr	hp/10'	bu/hr	hp/10'
300	200	.22	170	.25	130	.25	70	.19
400	260	.28	220	.32	180	.30	90	.25
600	380	.36	310	.44	230	.45	130	.36
800	430	.40	250	.52	290	.57	170	.46
1000	470	.43	380	.59	310	.69	190	.55

*Grain density 760 kg/m^3 (60 lb/bu)

Abstracted from: Les Convoyeurs, Pub 37 226, Quebec Ministere De L'Agriculture Division Du Machinisme Agricole 1973

TABLE 2.3.5 100 mm (4 in.) Auger Conveyor Handling Oats* With 150 mm (6 in.) Exposed Helix at Intake

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m
300	6.9	31.8	5.8	41.6	4.7	41.6	1.4	29.4
400	8.7	41.6	7.3	53.8	5.8	53.8	2.2	41.6
600	11.6	53.8	9.6	73.4	7.6	75.8	3.3	58.7
800	12.7	66.1	10.9	90.5	9.1	97.7	4.4	73.4
1000	12.7	70.9	10.9	100.3	9.6	110.1	4.9	85.6

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	bu/hr	hp/10'	bu/hr	hp/10'	bu/hr	hp/10'	bu/hr	hy/10'
300	190	.13	160	.17	130	.17	40	.12
400	240	.17	200	.22	160	.22	60	.17
600	320	.22	265	.30	210	.31	90	.24
800	350	.27	300	.37	250	.40	120	.30
1000	250	29	300	.41	265	.45	135	.35

*Grain density 430 kg/m^3(34 lb/bu)

Abstracted from:*Les Convoyeurs,* Pub 37 226, Quebec Ministere De L'Agriculture Division Du Machinisme Agricole 1973

TABLE 2.3.6 150 mm (6 in.) Auger Conveyor Handling Dry Shelled Corn*

Auger Speed	Intake Exposure	Angle of Elevation of Screw 0°		22.5°		45°		67.5°		90°	
rpm	mm	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m
	150	20.7	48.9	18.3	73.4	13.0	80.7	9.9	75.8	7.7	61.1
	300	20.7	68.5	19.4	100.3	17.6	107.6	14.1	107.6	9.9	78.3
200	460	21.8	78.3	20.1	105.2	18.0	115.0	15.1	110.1	10.9	88.1
	610	22.2	107.6	20.7	122.3	19.4	134.6	16.6	132.1	12.3	97.9
	150	34.2	85.6	29.9	127.2	22.9	146.8	16.9	139.5	13.4	122.5
	300	38.4	137.0	35.6	200.6	29.9	215.3	24.3	203.1	18.3	171.3
400	460	41.2	181.0	37.7	225.1	33.1	249.1	25.4	225.1	19.7	195.7
	610	41.9	237.3	39.1	376.5	35.6	288.7	29.2	261.8	23.3	225.1
	150	42.6	119.9	37.0	176.1	28.9	200.6	20.8	188.4	17.3	156.6
	300	53.2	205.5	49.3	298.5	40.9	313.2	32.1	283.8	25.4	256.9
600	460	58.1	286.2	52.9	247.4	44.7	371.9	35.6	347.4	28.2	300.9
	610	59.9	359.6	55.3	425.7	50.7	440.4	40.2	391.4	32.4	342.5
	150	46.5	141.9	38.8	210.4	31.4	232.4	22.6	225.1	19.0	188.4
	300	62.0	261.8	58.5	376.8	48.3	396.2	38.1	357.2	31.4	322.9
800	460	70.1	384.1	63.1	479.5	53.2	508.9	43.0	474.5	35.2	401.2
	610	75.4	477.1	67.3	561.6	61.3	584.1	47.9	518.7	38.8	462.4

Auger Speed	Intake Exposure	Angle of Elevation of Screw 0°		22.5°		45°		67.5°		90°	
rpm	in	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′
	6	590	.20	520	.30	370	.33	280	.31	220	.25
	12	590	.28	550	.41	500	.44	400	.44	280	.32
200	18	620	.32	570	.43	510	.47	430	.45	310	.36
	24	630	.44	590	.50	550	.55	470	.54	350	.40
	6	970	.35	850	.52	650	.60	480	.57	380	.46
	12	1090	.56	1010	.82	850	.88	690	.83	520	.70
400	18	1170	.74	1070	.92	940	1.02	720	.92	560	.80
	24	1190	.97	1110	1.13	1010	1.18	830	1.07	660	.92
	6	1210	.49	1050	.72	820	.82	590	.77	490	.64
	12	1510	.84	1400	1.22	1160	1.28	910	1.16	720	1.05
600	18	1650	1.17	1500	1.42	1270	1.52	1010	1.42	800	1.23
	24	1700	1.47	1570	1.74	1440	1.80	1140	1.60	920	1.40
	6	1320	.58	1100	.86	890	.95	640	.92	540	.77
	12	1760	1.07	1660	1.54	1370	1.62	1080	1.46	890	1.32
800	18	1990	1.57	1790	1.96	1510	2.08	1220	1.94	1000	1.64
	24	2140	1.95	1910	2.32	1740	2.39	1360	2.12	1100	1.89

*Grain density 675-700 kg/m^3 (54 to 56 lb/ft^3); 13.2 to 14% wet basis.

TABLE 2.3.7 150 mm (6 in.) Auger Conveyor Handling Dry Soybeans*

Auger Speed	Intake Exposure	Angle of Elevation of Screw									
		0°		22.5°		45°		67.5°		90°	
rpm	mm	m³/hr	W/m	m³/hr	W/m	m³/hr	W/m	m³/hr	W/m	m³/hr	W/m
200	150	17.3	73.4	14.4	100.3	11.3	100.3	8.5	93.0	6.3	83.2
	300	17.6	97.9	15.2	129.7	12.7	139.5	10.2	122.3	7.7	97.9
	460	18.3	122.3	17.6	146.8	15.5	161.5	12.7	146.8	8.5	110.1
	610	19.0	146.8	18.3	164.9	16.6	166.4	13.7	156.6	10.2	127.2
400	150	31.0	127.2	25.0	173.7	20.1	188.4	14.1	171.3	10.9	146.8
	300	34 9	205.5	29.2	278.9	24.3	293.6	19.0	254.4	13.7	193.3
	460	39.1	239.8	36.3	288.7	31.0	315.6	26.1	300.9	16.2	232.4
	610	41.6	332.7	36.6	376.3	31.7	398.8	28.2	376.8	19.7	278.9
600	150	38.1	166.4	31.4	234.9	24.7	361.8	18.0	244.7	13.7	212.8
	300	47.6	293.6	39.8	393.9	32.8	418.4	25.0	362.1	17.6	269.1
	460	57.1	354.7	53.2	425.7	45.1	474.6	37.0	459.9	23.3	359.6
	610	59.5	521.1	53.6	616.5	46.5	614.1	38.8	561.6	27.8	430.6
800	150	41.6	190.8	33.8	274.0	26.1	313.2	19.4	298.5	14.0	269.1
	300	56.7	369.4	46.2	484.4	38.1	513.8	28.9	450.2	22.6	267.0
	460	69.8	472.2	64.8	560.3	53.9	621.4	43.3	597.0	28.5	494.4
	610	71.2	716.8	65.2	839.2	57.8	851.4	46.5	792.7	35.2	626.3

Auger	Intake Exposure	Angle of Elevation of Screw									
		0°		22.5°		45°		67.5°		90°	
rpm	in	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′
200	6	490	.30	410	.41	320	.41	240	.38	180	.34
	12	500	.40	430	.53	360	.57	290	.50	220	.40
	18	520	.50	500	.60	440	.66	360	.60	240	.45
	24	540	.60	520	.67	470	.68	390	.64	290	.52
400	6	880	.52	710	.71	570	.77	400	.70	310	.60
	12	990	.84	830	1.14	690	1.20	540	1.04	390	.79
	18	1110	.98	1030	1.18	880	1.29	740	1.23	460	.95
	24	1180	1.36	1040	1.62	900	1.63	800	1.54	560	1.14
600	6	1080	.68	890	.96	700	1.07	510	1.00	390	.87
	12	1350	1.20	1130	1.61	930	1.71	710	1.48	500	1.10
	18	1620	1.45	1510	1.74	1280	1.94	1050	1.88	660	1.47
	24	1690	2.13	1520	2.52	1320	2.51	1100	2.32	790	1.76
800	6	1180	.78	960	1.12	740	1.28	550	1.22	420	1.10
	12	1610	1.51	1310	1.98	1080	2.10	820	1.84	640	1.50
	18	1980	1.93	1840	2.29	1530	2.54	1230	2.44	810	1.98
	24	2020	2.93	1850	3.43	1640	3.48	1320	3.24	1000	2.56

*Grain density 675-700 kg/m³ (54 to 56 lb/ft³); 13.2 to 14% wet basis.

TABLE 2.3.8 150 mm(6 in.) Auger Conveyor Handling Dry, vs. Handling Wet, Shelled Corn*

Auger Speed	Corn Moisture	Angle of Elevation of Screw Conveyor									
		0°		22.5°		45°		67.5°		90°	
rpm	%	m³/hr	W/m	m³/hr	W/m	m³/hr	W/m	m³/hr	W/m	m³/hr	W/m
200	14	20.9	68.5	19.5	100.3	17.5	107.6	14.2	107.6	9.7	78.3
	25	13.1	335.2	11.2	342.5	9.9	320.5	7.2	237.3	5.5	78.3
400	14	38.3	137.0	35.5	200.6	30.0	215.3	24.3	203.1	18.2	171.3
	25	24.5	450.2	21.8	462.4	18.0	435.5	14.2	354.7	10.6	171.3
600	14	53.1	205.5	49.5	298.5	41.0	313.2	31.9	283.8	26.2	256.9
	25	33.2	567.5	29.0	572.5	23.9	555.4	18.2	469.7	13.3	266.7
800	14	62.2	261.8	58.4	376.8	48.2	396.3	38.1	357.2	31.3	322.9
	25	38.7	685.0	33.4	697.3	27.5	672.8	20.5	597.0	16.7	379.2

continued

Auger Speed	Corn Moisture	Angle of Elevation of Screw Conveyor									
		0°		22.5°		45°		67.5°		90°	
rpm	%	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′
200	14	595	.28	552	.41	498	.44	402	.44	278	.32
	25	372	1.37	318	1.40	282	1.31	204	.97	156	.32
400	14	1086	.56	1008	.82	852	.88	690	.83	516	.70
	25	696	1.84	618	1.89	510	1.78	402	1.45	300	.70
600	14	1512	.84	1404	1.22	1164	1.28	906	1.16	744	1.05
	25	948	2.32	822	2.34	678	2.27	516	1.92	378	1.09
800	14	1764	1.07	1656	1.54	1368	1.62	1080	1.46	888	1.32
	25	1098	2.80	948	2.85	774	2.75	582	2.44	474	1.55

*Moisture contents of 14 to 25% wet basis; 300 mm (12 in.) exposed helix at screw inlet

TABLE 2.3.9 150 mm (6 in.) Auger Conveyor Handling Wheat* With 150 mm (6 in.) Exposed Helix at Intake

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m
300	26.6	122.3	22.2	141.9	15.6	137.0	8.4	107.6
400	32.4	129.7	25.8	171.3	19.6	168.8	12.0	139.4
600	38.9	144.3	30.9	210.4	23.6	220.2	15.6	193.3
800	39.3	156.6	31.3	239.8	24.0	259.3	16.4	249.5
1000	38.9	161.5	30.6	269.1	23.6	298.5	16.0	293.6

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′
300	730	.50	610	.58	430	.56	230	.44
400	890	.53	710	.70	540	.69	330	.57
600	1080	.59	850	.86	650	.90	430	.79
800	1080	.64	860	.98	660	1.06	450	1.02
1000	1070	.66	840	1.10	650	1.22	440	1.20

*Bushel Weight 27 kg(60 lb.)
Abstracted from: *Les Convoyeurs*, Pub. 37 226, Quebec Ministere De L'Agriculture Division Due Machinisme Agricole 1973

TABLE 2.3.10 150 mm (6 in.) Auger Conveyor Handling Oats* With 150 mm (6 in.) Exposed Helix at Intake

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m	m^3/hr	W/m
300	25.6	53.8	20.7	73.4	15.6	80.7	8.7	61.2
400	30.0	58.7	24.0	80.7	18.2	90.5	10.2	75.8
600	34.7	68.5	26.5	97.9	20.4	117.4	12.4	102.7
800	35.6	80.7	27.1	117.4	20.6	137.0	13.5	217.2
1000	33.3	97.9	25.8	141.9	19.3	163.9	13.5	151.7

Auger Speed	Angle of Elevation							
	10°		30°		50°		90°	
rpm	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′	bu/hr	hp/10′
300	705	.22	570	.30	430	.33	240	.25
400	825	.24	660	.33	500	.37	280	.31
600	955	.28	730	.40	560	.48	340	.42
800	980	.33	745	.48	565	.56	370	.52
1000	915	.40	710	.58	530	.67	370	.62

*Grain density 430 kg/m^3 (34 lb/bu)
Abstracted from: *Les Convoyeurs*, Pub 37 226, Quebec Ministere De L'Agriculture Division Du Machinisme Agricole 1973

TABLE 2.3.11 Power Requirements for 150 to 300 mm (6 to 12 in.) Diameter Portable Augers Inclined at 40 to 45 Degrees

Diameter mm	Auger Length m	Rated Capacity* m^3/hr	Grain Elevated m	Minimum Power (electric) W	Auger Speed rpm
150	8.2	52.9	5.3	2237	500
	10.1		6.5	2237	to
	12.5		8.4	2237	650
	14.3		10.0	3728	
	16.2		11.3	3728	
	17.4		11.9	5593	
	18.9		13.2	5593	
200	10.1	88.1	6.4	3728	450
	14.3		9.9	3728	to
	17.4		11.7	5593	500
	21.6		15.0	11185	
250	9.5	127.0	6.3	5593	350
	15.5		10.6	11185	to
	18.6		12.8	11185	450
	21.6		15.0	14914	
300	9.5	158.6	6.3	7457	300
	12.5		7.9	11185	to
	15.5		10.6	11185	400
	18.6		12.8	14914	

in.	ft	bu/hr	ft	hp	Auger Speed rpm
6	27	1500	17.5	3	500
	33		21.5	3	to
	41		27.5	3	650
	47		32.8	5	
	53		37.0	5	
	57		39.0	7½	
	62		44.0	7½	
9	33	2500	21.0	5	450
	47		32.5	5	to
	57		38.5	7½	500
	71		49.3	15	
10	31	3600	20.8	7½	350
	51		34.8	15	to
	61		42.0	15	450
	71		49.1	20	
12	31	4500	20.8	10	300
	41		26.0	15	to
	51		34.8	15	400
	61		42.0	20	

*Based on dry grain

Horizontal feed augers can be placed in U shaped troughs. The capacity will be dependent on the auger diameter and its speed (rpm). Figure 2.3.2 is a nomograph for determining speed or capacity for a 230 mm (9 in.) U trough auger and Figure 2.3.3 is a nomograph for determining speed or capacity for a 300 mm (12 in.) U trough auger. With the auger speed known Table 2.3.13 can be used to select the required pulley sizes.

Lengths of portable augers such as the one shown in Figure 2.3.4 can be determined from the nomograph provided in Figure 2.3.5.

2.3.2 AUGER BIN UNLOADERS

The usefulness and versatility of auger conveyors has been extended by the use of units designed to unload free flowing materials such as grains from storage.

One arrangement illustrated in Figure 2.3.6, consists of a screw conveyor mounted under the bin with a demountable drivehead and screw which can be easily removed for attaching to other similar units. Another portable arrangement is a screw conveyor and tube which slides into an outer tube which may extend from outside

TABLE 2.3.12 Power Requirements for Custom Built Distributing Augers

Auger Size	150 mm	200 mm	250 mm	300 mm
Motor Size	Length of auger			
W	m	m	m	m
	Horizontal Augers			
1120	5.0	—	—	—
1490	8.0	5.0	3.0	—
2240	14.0	8.0	6.0	5.0
3730	21.0	15.0	11.0	8.0
5590	33.0	24.0	15.0	12.0
7460	—	33.0	25.0	15.0
11190	—	—	33.0	24.0
Capacity m^3/hr	32 - 42	53 - 70	88 - 123	141 - 176
	Vertical Augers			
1491	5.0	3.0	—	—
2237	8.0	5.0	3.0	—
3728	11.0	8.0	5.0	4.0
5593	14.0	11.0	8.0	6.0
7457	18.0	15.0	12.0	9.0
Capacity m^3/hr	9 - 11	21 - 28	32 - 42	63 - 88
Auger Size	6 in.	8 in.	10 in.	12 in.
Motor Size hp	ft	ft	ft	ft
	Horizontal Augers			
1½	15	—	—	—
2	25	15	10	—
3	45	25	20	15
5	70	50	35	25
7½	110	80	50	40
10	—	110	80	50
15	—	—	110	80
Capacity bu/hr	900 - 1200	1500-2000	2500-3500	4000-5000
	Vertical Augers			
2	15	10	—	—
3	25	15	10	—
5	35	25	15	12
7½	45	35	25	20
10	60	50	40	30
Capacity bu/hr	250 - 300	600 - 800	900 - 1200	1800-2500

These recommendations are to be used as a guide. Requirements will vary with the condition and kind of grain, loading factor, rpm, kind of material conveyed, use of reduction, etc. For high moisture use a 1.5 multiplier for power. That is, where a 7.45 kW(10 hp) motor will handle dry grain, an 11.2 kW (15 hp) for high moisture grain is recommended.

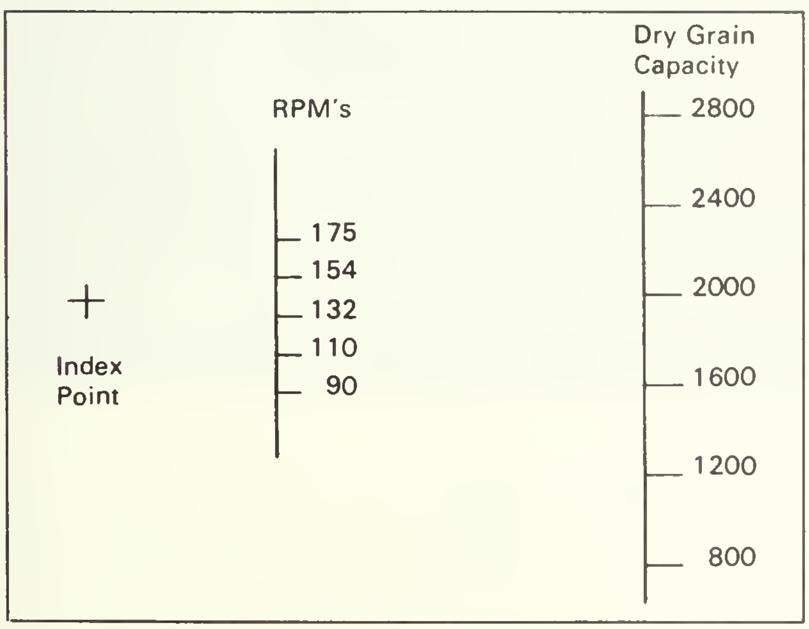


Figure 2.3.2 Capacity-rpm calculations for 230 mm (9 in.) U trough horizontal augers.

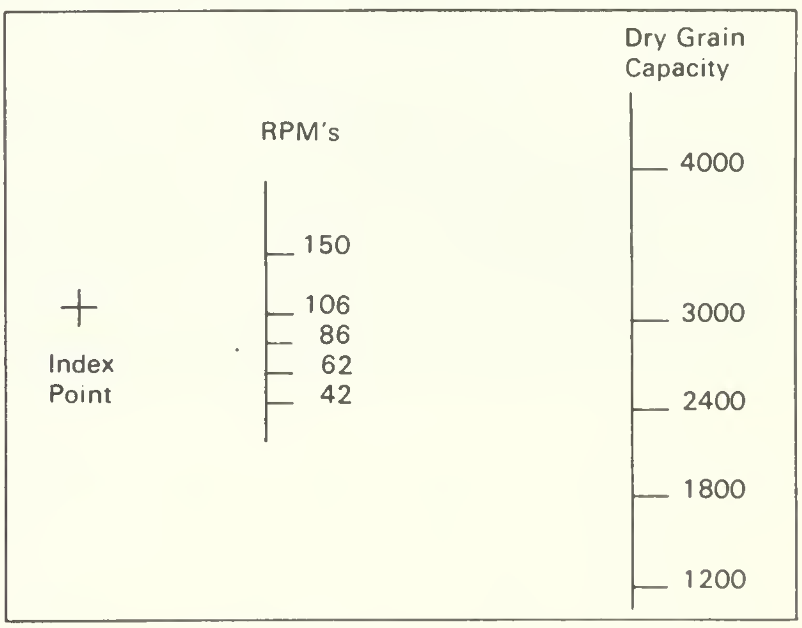


Figure 2.3.3 Capacity-rpm calculation for 300 mm (12 in.) trough horizontal augers.

TABLE 2.3.13 Pulley Size for Selected Auger Speeds at Motor Speed 1750 rpm

Drive Pulley		Drive Pulley		Auger rpm (speed ratio 1:1)	Auger rpm (speed ratio 2.77:1)
mm	in	mm	in		
76	3	229	9	583	210
76	3	305	12	438	158
76	3	381	15	350	126
76	3	457	18	292	105
89	3.5	229	9	681	246
89	3.5	305	12	510	184
89	3.5	381	15	429	155
89	3.5	457	18	340	123
102	4	229	9	778	248
102	4	305	12	583	210
102	4	381	15	467	169
102	4	457	18	389	140
114	4.5	229	9	875	316
114	4.5	305	12	655	236
114	4.5	381	15	526	190
114	4.5	457	18	438	158
127	5	229	9	972	351
127	5	305	12	729	263
127	5	381	15	583	210
127	5	457	18	486	175

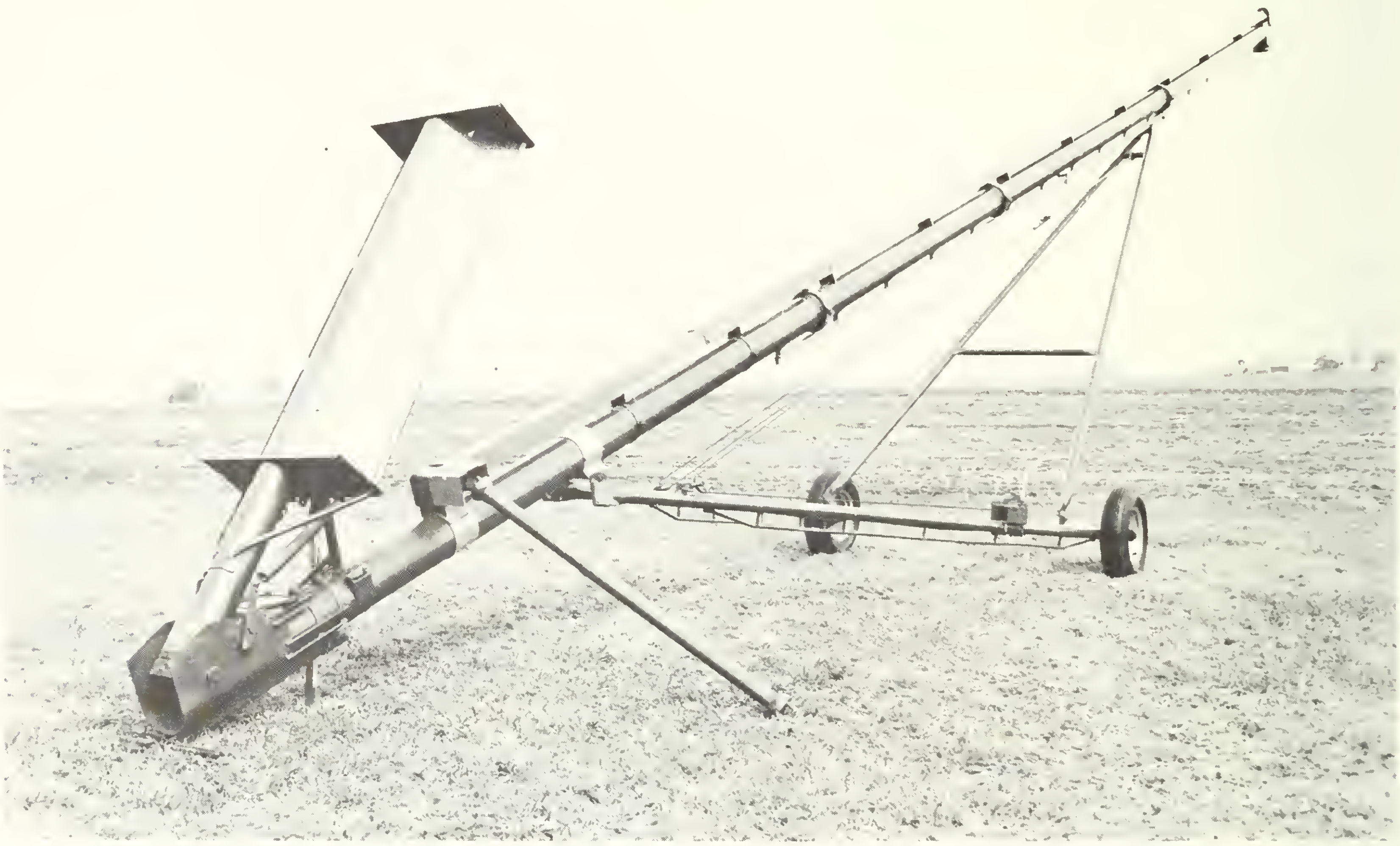
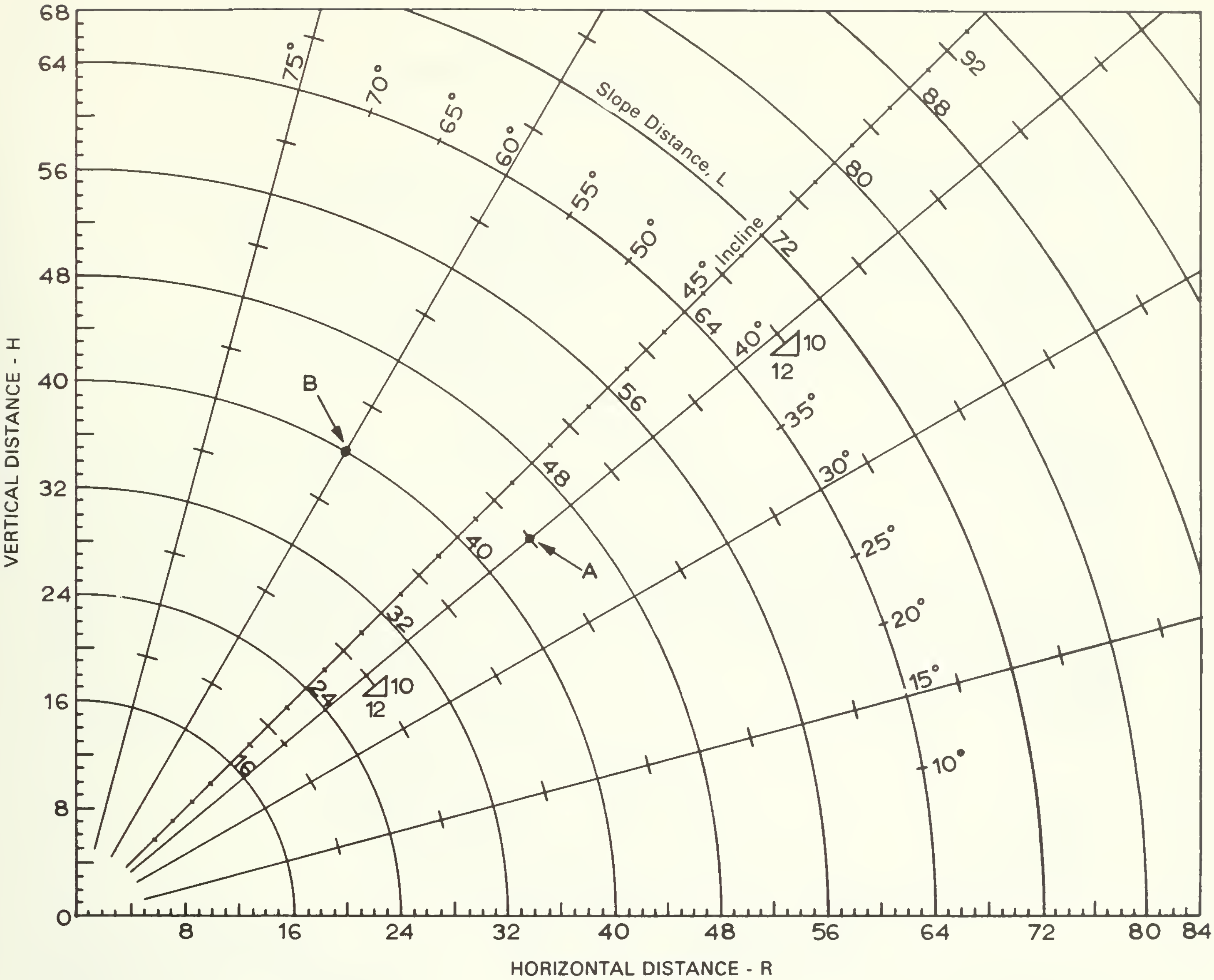


Figure 2.3.4 Portable auger conveyor. Courtesy: Kewanee Machinery Division Chromalloy



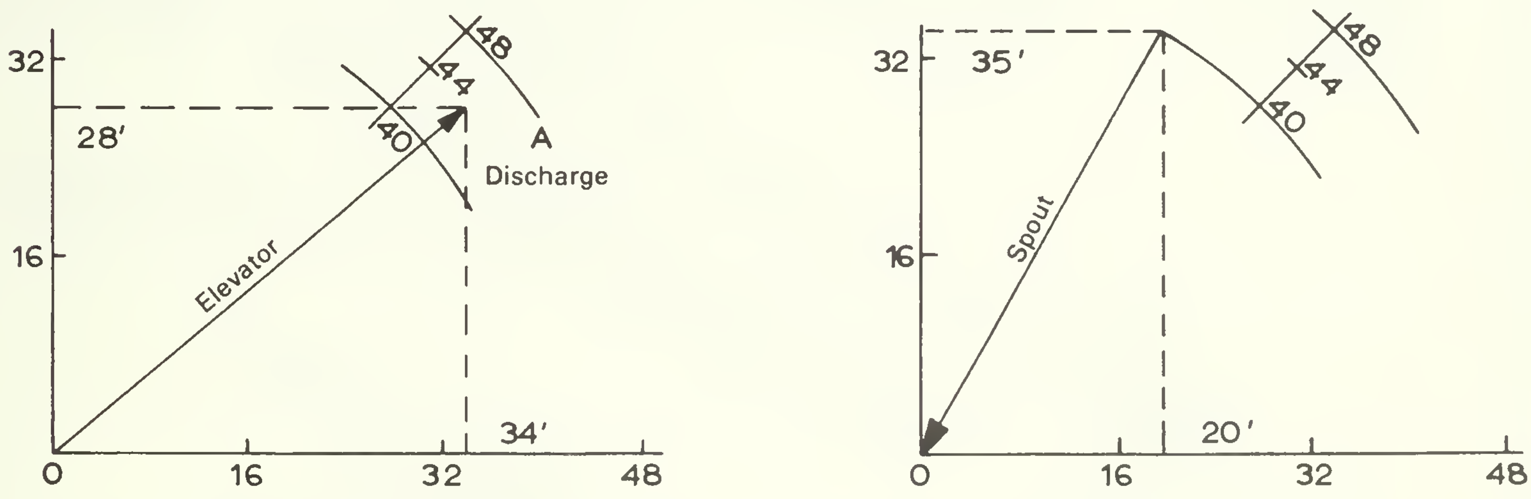


Figure 2.3.5 Conveyor length, distance and discharge height chart. Reproduced with permission fro MWPS-13, *Planning Grain-Feed Handling*, Midwest Plan Service, Ames, IA 50011

the building into the center. The conveyor with a section of exposed flighting at the intake end is inserted into the tube until contact with the grain is made. A push on the conveyor with the power on and the unit will "auger" into the center. Another installation consists of an exposed auger whose length is the radial dimension of the bin. A wheel of slightly larger diameter is mounted on the outer end of the auger to hold it off the floor of the bin. The auger will maintain contact with the face of grain as it operates and makes one revolution in unloading the bin, maintaining a constant flow into a central hopper. Figures 2.3.6 and 2.3.7 illustrate these arrangements.

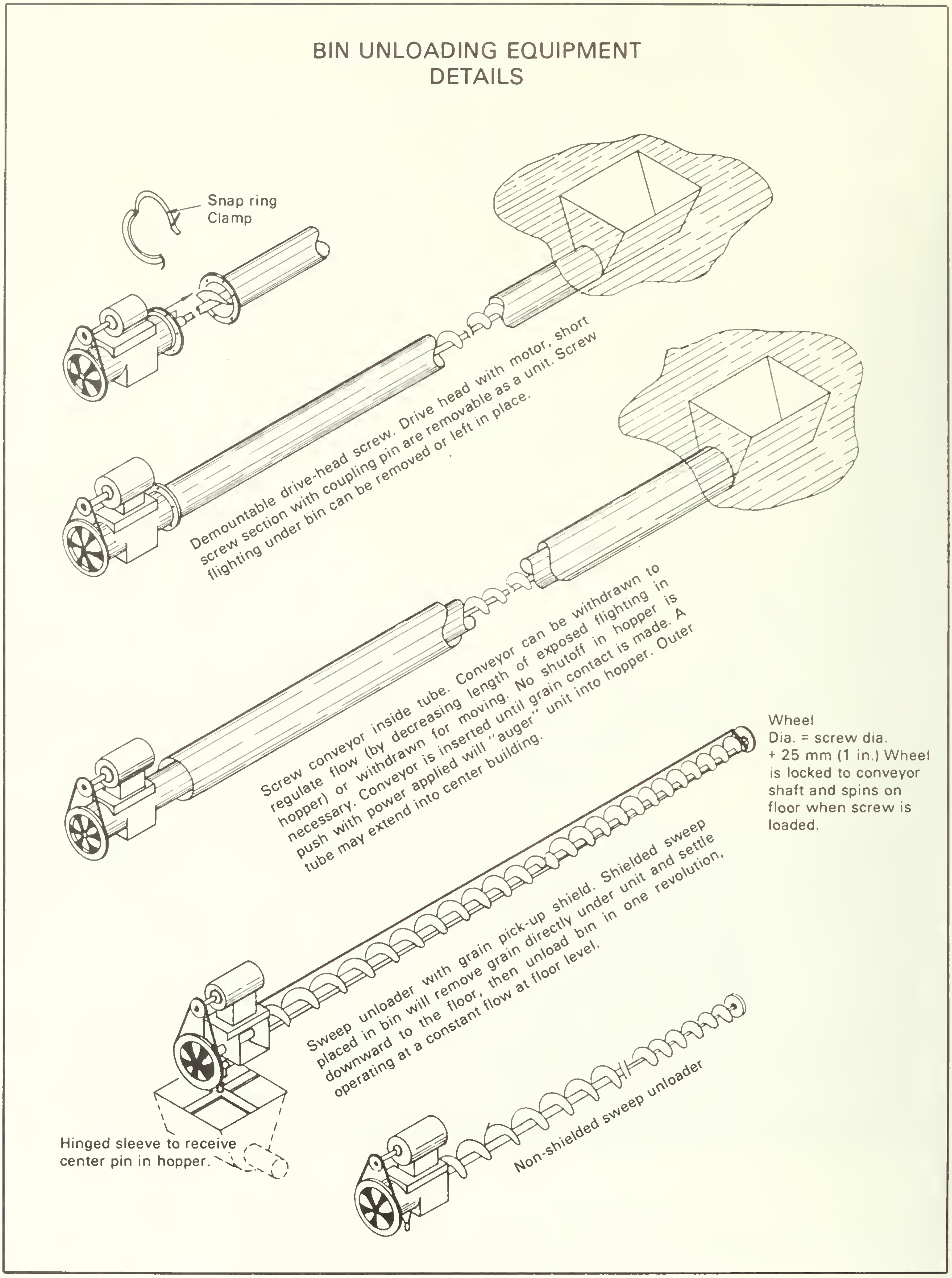


Figure 2.3.6 Round bin unloading equipment. Reproduced with permission from MWPS-13 *Planning Grain- Feed Handling*, Midwest Plan Service, Ames, IA 50011

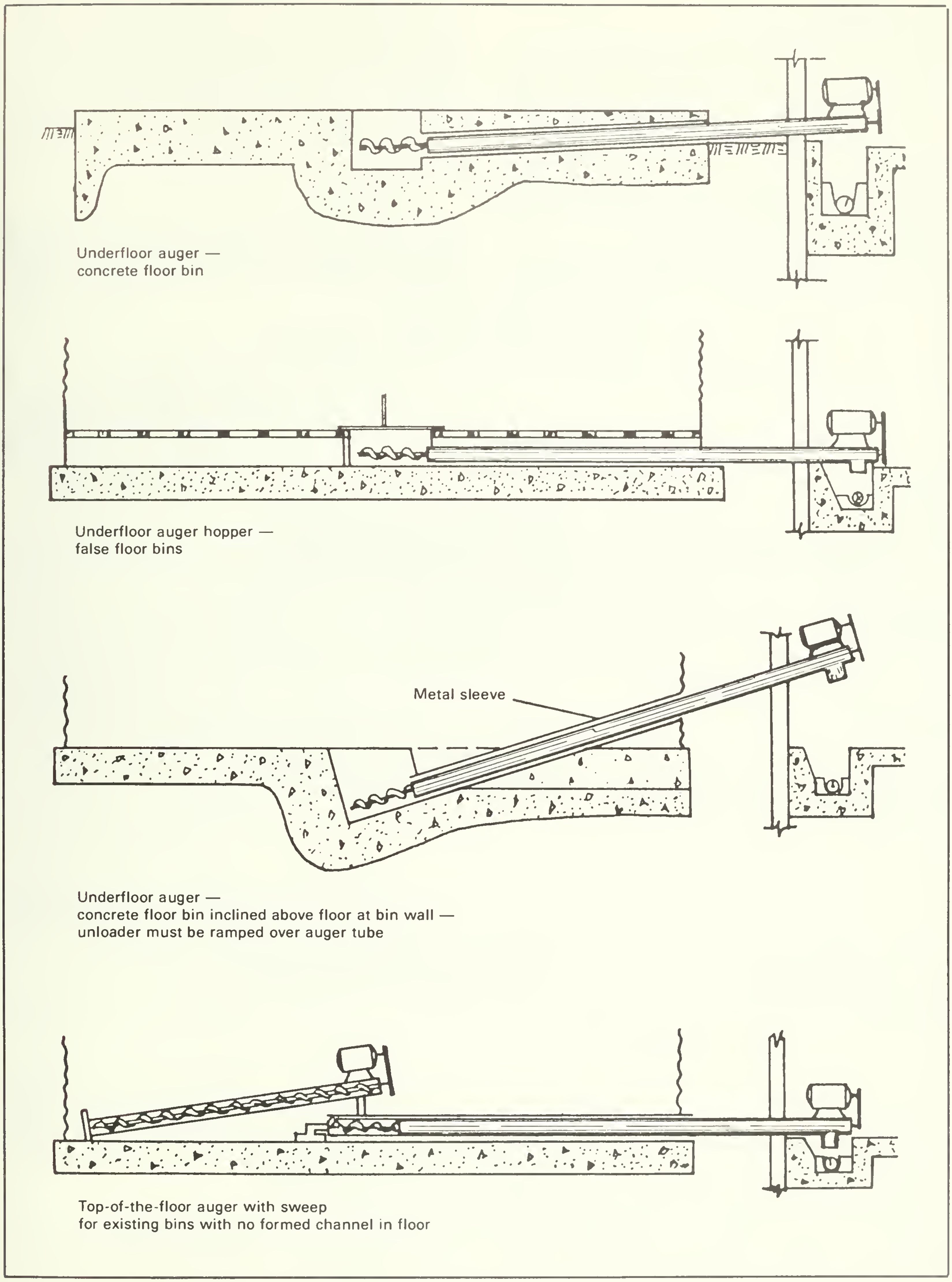


Figure 2.3.7 Round bin unloading floor arrangements. Reproduced with permission from MWPS-13, *Planning Grain-Feed Handling*, Midwest Plan Service, Ames IA 50011

2.3.3 AUGER CONVEYORS FOR MECHANICAL FEEDING

Auger-type bunk-feeders are relatively simple with only one moving part in the bunk and are highly resistant to freeze-up in winter. Their major disadvantages are high power requirements and a tendency to separate coarse materials from fine, and heavy particles from lighter ones.

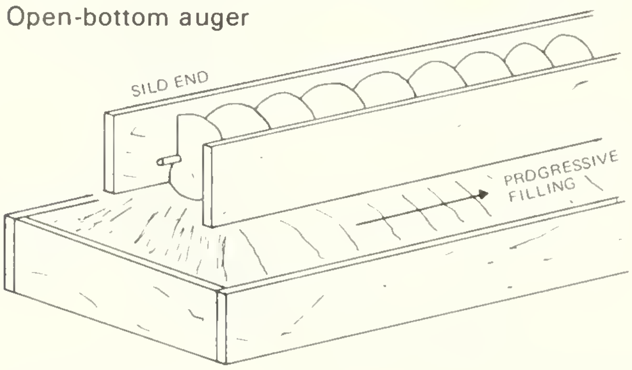
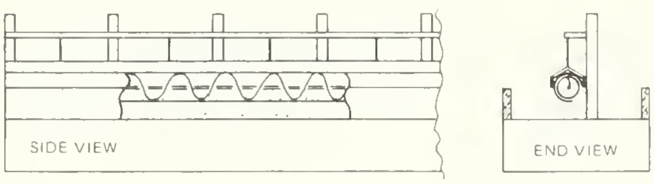
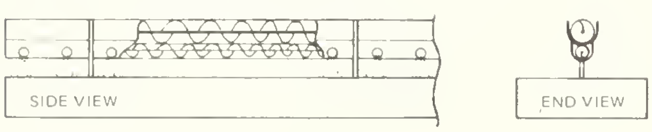
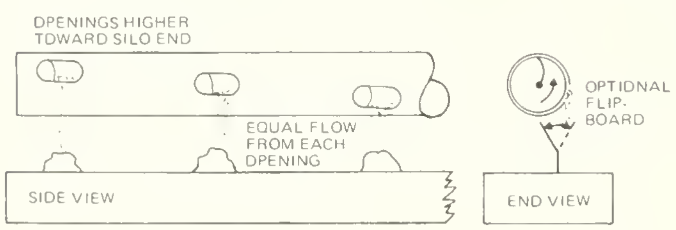
Most auger-type bunk-feeders operate at a speed between 100 and 225 rpm. Figure 2.3.8 shows various types of auger-bunk feeders. These feeders require four to five times as much power as the same length of chain or belt feeder. If single phase power is used the bunk length will be limited to about 47 m (150 ft).

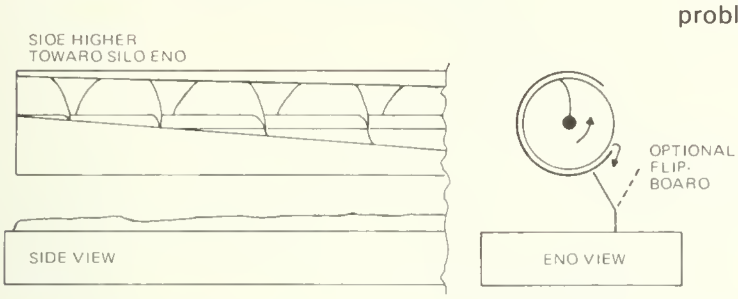
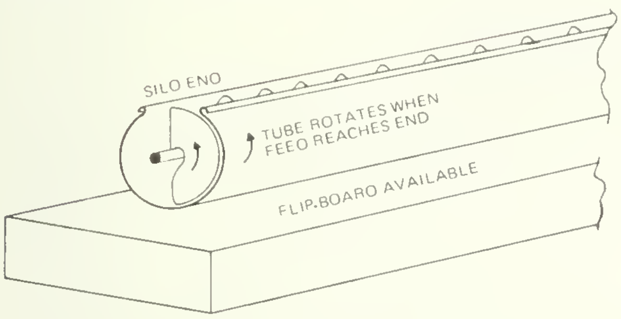
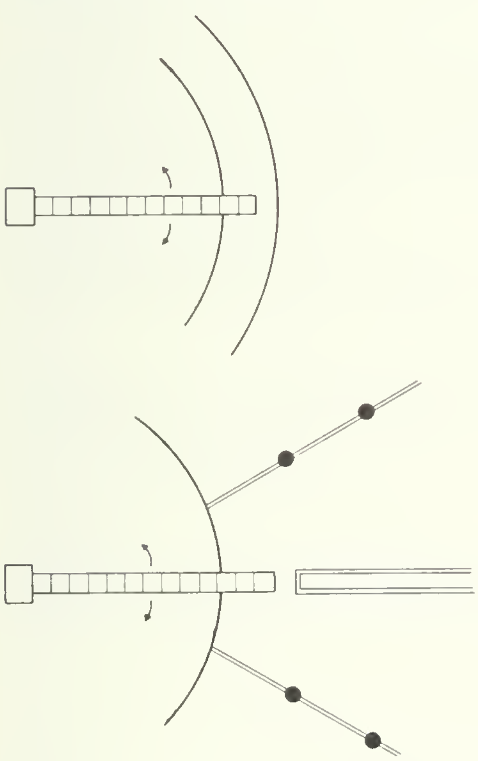
Studies by Bellman (2) show that auger type feeders will deliver about 2900 kg/kWh (6400 lb/kWh). Moisture content or degree of fineness did not influence efficiency in any predictable manner. High-moisture grain and low-moisture silage however, are difficult to distribute evenly. Where feed mixtures are used the auger feeder tended to provide some mixing as distribution took place, which is not true for chain type conveyors. The efficiency of auger feeders is decreased more by low-moisture silage than are other types of feeder units. More complete assessment of conveyor systems for bunk feeding is given in Section 2.1.

2.3.4 AUGER CONVEYORS FOR FERTILIZERS

Auger conveyors can be used to handle fertilizer provided the auger is cleared of fertilizer at the end of each use. Fertilizer compacts rapidly and will clog the auger. Power

Figure 2.3.8 Varieties of auger-type bunk feeders. (From: *Farm Feed Processing and Handling*. Agric. Canada Pub. 1572, 1976)

Type of auger feeder	Comments	Approx kW for 10 m bunk	Approx hp for 100-ft bunk	No. pens normally serviced
Open-bottom auger 	Delivers more feed to first part of bunk than to last, unless vertical distance between bunk floor increases towards far end of bunk. Feed separation occurs along feed bunk when silage and grain are fed together.	1.1-1.7	5-7½	1
Cradle feeder 	Works much like an open-bottom auger unit, but uses less power, Amount of feed dropped each feeding can be regulated by adjusting height of the partly enclosed tube.	0.5-0.7	2-3	1
Auger-fill, auger-dump feeder 	Top auger fills a series of secondary hoppers. When far end of hopper unit is full, a switch starts lower auger, which discharges ration through fixed ports.	0.7-1.1	3-5	2+
Perforated-tube proportional drop feeder 	When feed reaches its far end, unit fills entire length of bunk at once. Rotating so holes are on bottom and all material is removed from auger, this feeder causes considerable separation between coarse and fine particles.	0.7-1.1	3-5	2+

Type of auger feeder	Comments	Approx kW for 10 m bunk	Approx hp for 100-ft bunk	No. pens normally serviced
Tapered-side proportional drop feeder 	Operates as above, but separation is not a problem.	0.3-0.7	1½-3	2
Revolving tube feeder 	When filled, trips a switch, dumps and returns to upright position for another cycle. Procedure is repeated until desired amount of feed is placed over full length of bunk.	0.7-1.1	3-5	2
Swinging overhead feeder 	Serves as a bunk feeder by traveling back and forth over a circular bunk. A chain-type conveyor can be used instead of the auger, lowering power requirements. Strong winds can be a problem with dry feeds, as all feed must drop several feet into the bunk. Another alternative shown is a swinging conveyor filling bunk feeders in several pens.	0.3-0.7	1½-3	2+

requirements are greater than for conveying wheat for the same conveyor incline. Figure 2.3.9 shows a comparison of throughput and power requirements for the same auger when conveying wheat or 11-48-0 fertilizer (11).

2.3.5 GRAVITY CHUTES

Spouts for conveying materials from bulk storage bins or from elevator heads are inclined at an angle greater than the angle of friction between the material and the bin surface for the material with the poorest flowability. The moisture content of the material has a pronounced effect on its flow characteristics. Gravity chutes to handle all grains should be inclined at least 45°, while 60° is recommended for all ground feed products. Material in bags or boxes can be conveyed down chutes inclined at 30°. Hay bales will slide down 45° chutes satisfactorily.

The type of material used in the spout construction greatly influences the angle of inclination and will provide trouble-free flow. Smooth shiny metal has a lower coefficient of friction than plywood, especially if material-flow is across the grain of the plywood. Wood chutes must

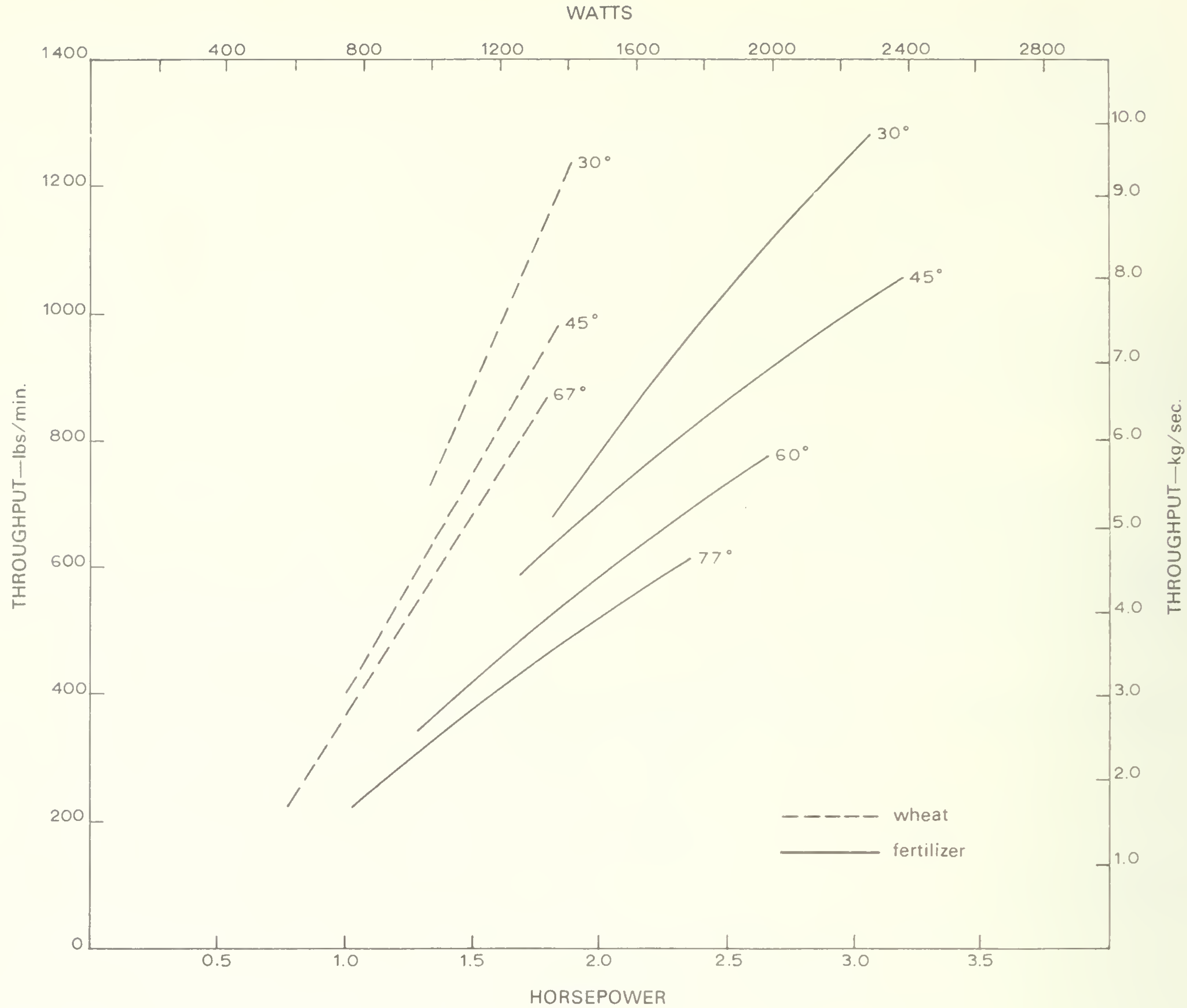


Figure 2.3.9 Power requirements vs. throughput of auger conveyor while conveying an 11-48-0 fertilizer at angles of inclination shown

be smooth and free from knots. Chutes and spouts may be rectangular or circular in cross-sections. They may be open chutes, or fully closed to prevent dust and contamination of the product by insects, odors or foreign bodies. When carefully constructed, with no sharp corners or small obstructions, spouts have the advantage of being self-cleaning.

The rate of flow is a function of the spout incline, coefficient of friction of the product on the spout material, the internal friction of the product, and the initial velocity of the product when it entered the spout.

Figure 2.3.5 provides a graphical solution to determining slope distance, vertical distance and horizontal run for gravity spouts, chutes and conveyors. Recommended sizes of spouts for several capacities are given in Table 2.3.14 (5).

Gravity chute design should always be based on handling the hardest to flow material that will be expected to flow through the chutes.

2.3.6 BUCKET ELEVATORS

2.3.6.1 General

Where the vertical transport of loose or free flowing material through a limited height is required some form of a bucket elevator is a convenient solution. Feeding of the elevator is usually done by flooding the lowest portion of the boot so that buckets attached to a vertical belt scrape up the material. Discharge takes place at the top over the head or drive pulley. One discharge method is a combination of centrifugal and gravity forces for non-sticky materials. Speeds will be in the order of 1 to 4 m/s

TABLE 2.3.14 Capacity of Gravity Spouts

Capacity t/hr	Material	Spout Slope o	Min Spout Diam mm
18 - 36	Grain	35	150 or
	Soft Ingredients	60	150 square
36 - 54	Grain	35	200 or
	Soft Ingredients	60	180 square
54 - 73	Grain	35	250 or
	Soft Ingredients	60	230 square
tons/hr		o	in.
20 - 40	Grain	35	6 or
	Soft Ingredients	60	6 square
40 - 60	Grain	35	8 or
	Soft Ingredients	60	7 square
60 - 80	Grain	35	10 or
	Soft Ingredients	60	9 square

Gravity chute design should always be based on handling the hardest to flow material that will be expected to flow through the chutes

(200 to 790 ft/min). Discharge chutes guide the material away to storage bins or other conveyor systems. For slightly sticky materials (feeds containing molasses or tallow) gravity discharge can be used. The buckets are usually closer together so that at the point of discharge the outside of the lower bucket forms a chute for material falling from the bucket immediately above. The speed of these elevators is limited to about 0.5m/s (100 ft/min). The gravity discharge method is seldom recommended for agricultural situations.

Buckets or cups are made of pressed steel, linear polyethelene, aluminum, brass, copper and stainless steel. Pressed steel is the most popular for on-farm installations. Many bucket designs are available for specific applications and manufacturers' catalogues should be consulted before final recommendations are made.

The size of a bucket elevator installation will usually be governed by the harvesting rate, although drying processes or load-out rates could be of prime consideration. Table 2.3.15 summarizes recommendations for size selection. Figure 2.3.10 shows the principal components of a bucket elevator.

TABLE 2.3.15 Recommended Sizes of Bucket Elevators

Capacity			
m^3/hr	bu/hr	Comments	Applications
18 - 25	500 - 700	Well suited to wet and dry grain handling on continuous flow dryer.	1. Small farm needs. 2. Feed making only with separate elevators for receiving wet grain. 3. As wet and dry grain elevator on continuous flow dryer.
35 - 42	1000 - 1200	Well matched to 150 mm (6 in.) augers and gravity spouts.	1. Small and medium farms, feed and/or cash grain. 2. Small batch dryers, and layer or batch-in-bin drying methods on small to medium farms.
53 - 70	1500 - 2000	Well matched to commercial batch dryer rates. Maximum size for 150 mm (6 in.) gravity spouts. Maximum size for 200 mm (8 in.) horizontal augers.	1. Medium to large farms feed and cash grain. 2. Batch and batch-in-bin drying systems. 3. Primary leg in continuous flow batch drying system.
88 - 160	2500 - 3000	Matched to 200 mm (8 in.) augers and gravity chutes.	1. Large farms, feed and cash grains. 2. Large batch and batch-in-bin drying systems. 3. Primary leg in two-leg installations on continuous flow dryers.

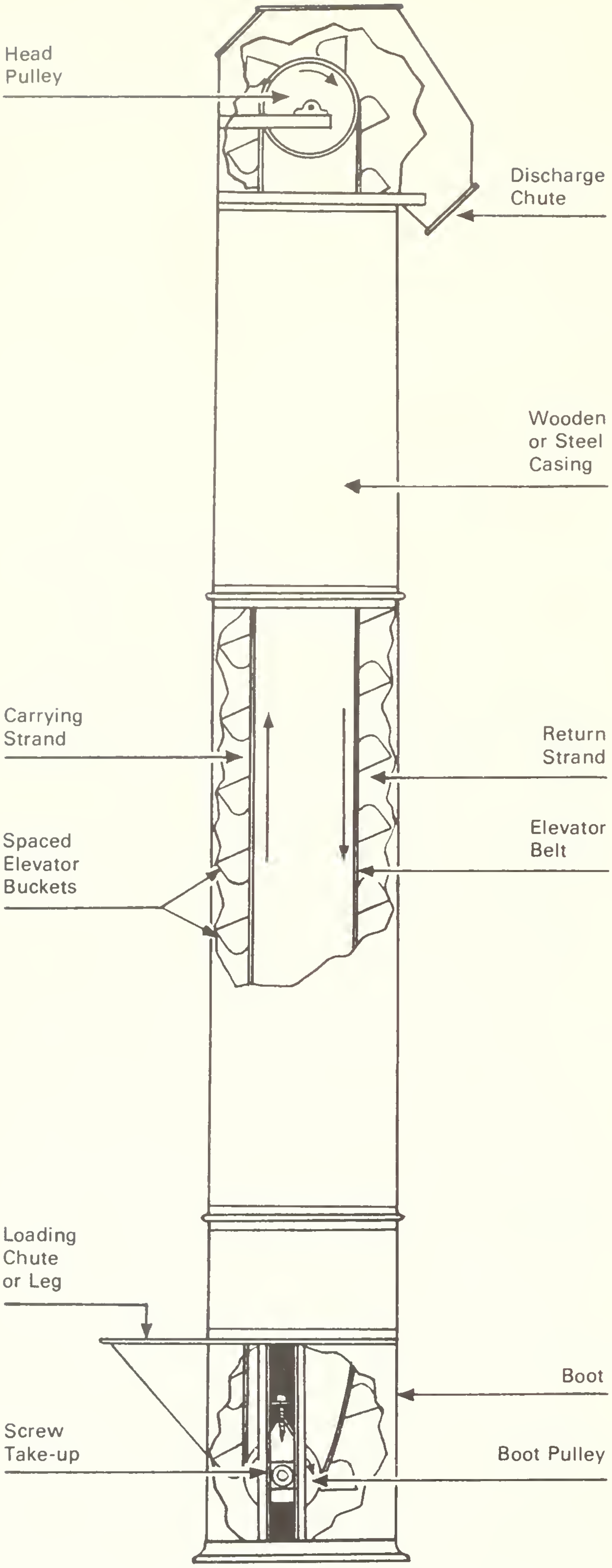


Figure 2.3.10 Bucket elevator, showing principal parts

2.3.6.2 Elevator Speed

Two forces, the weight of material within the bucket and the centrifugal force, act upon the material in the buckets as they move over the head pulley. the centrifugal force due to rotation of the material is given by:

$$F_c = \frac{MV^2}{R} \qquad [4]$$

where F_c = centrifugal force (N)
M = mass of material (kg)
V = tangential velocity of the mass (m/s)
R = effective radius of the center of rotation (m).

Referring to Figure 2.3.11 the resultant (X) of the centrifugal force and the gravitational force determines the point at which discharge takes place. Frequently bucket elevators are designed so that the centrifugal force equals the gravitational force at or near the top of the cup travel, thus

$$F_c = Mg = \frac{MV^2}{R} \qquad [5]$$

from which $V^2 = Rg$. The peripheral velocity is related to the rate of rotation n of the head pulley as shown in Figure 2.3.11. In the SI units:

$$V = 2\pi Rn \qquad [6]$$

then since $\pi \simeq \sqrt{g}$

$$N = \frac{1}{2\sqrt{R}} \qquad [7]$$

2.3.6.3 Capacity

The capacity of a bucket elevator may be expressed as:

$$T = \frac{CbV}{S} \qquad [8]$$

where T = capacity (kg/s)
C = usable bucket capacity (m^3)
V = belt speed (m/s)
b = bulk density of material (kg/m^3)
S = bucket spacing on the belt (m)

2.3.6.4 Energy Requirements

The main power requirements are for raising the material through a height H in meters. To allow for friction in the head and boot etc. an additional 20% should be added to the theoretical power required when loading on the up side, or 50% added when loading on the down side. An allowance of 85% for motor and drive efficiency is also required. Therefore, the required drive motor size in watts is given by:

$$P = \frac{1.2\,T\,g\,H}{0.85} \qquad [9]$$

where T = amount of material conveyed (kg/s)
g = 9.8 m/s^2
H = height material is elevated (m)

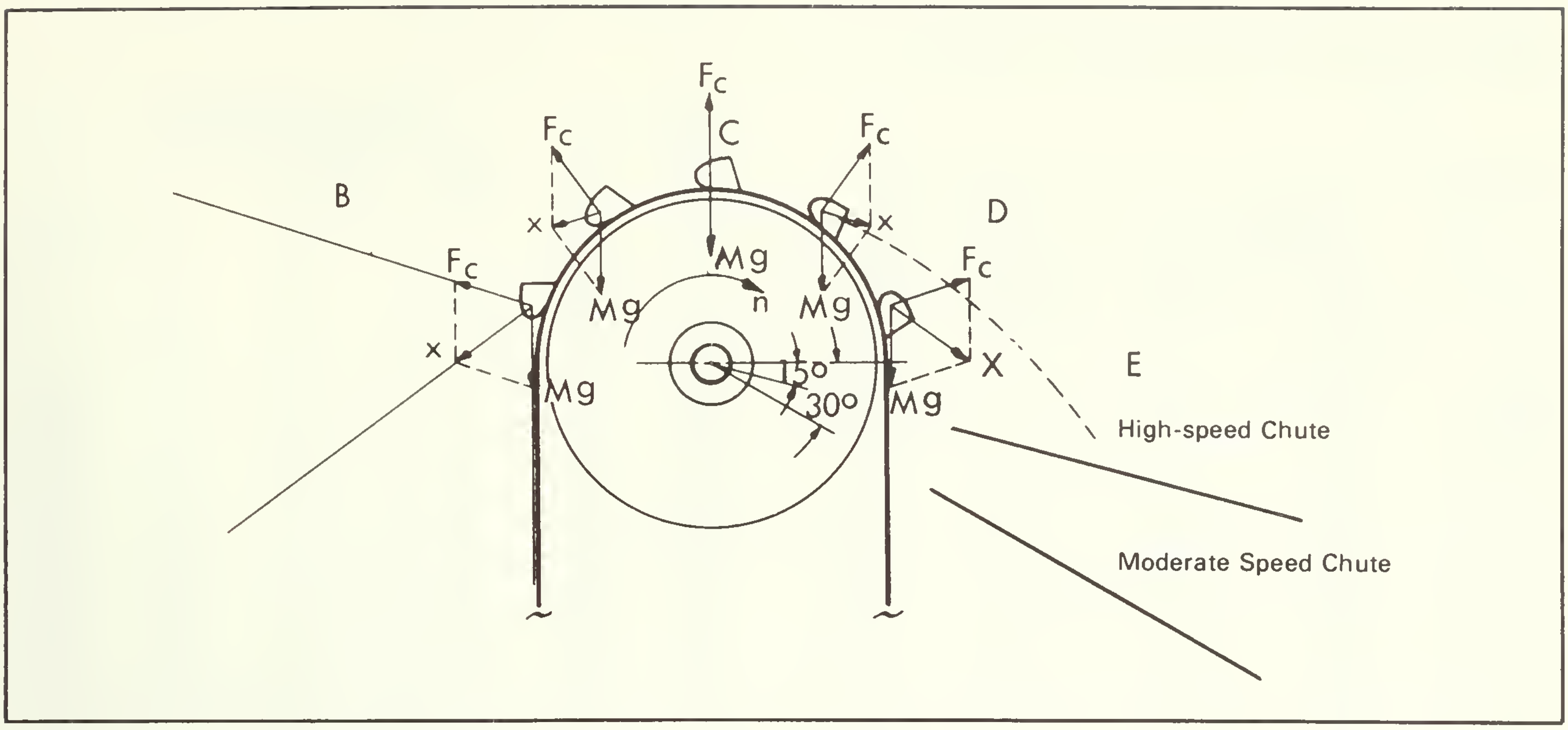


Figure 2.3.11 Resultant forces on material in bucket at elevator head pulley

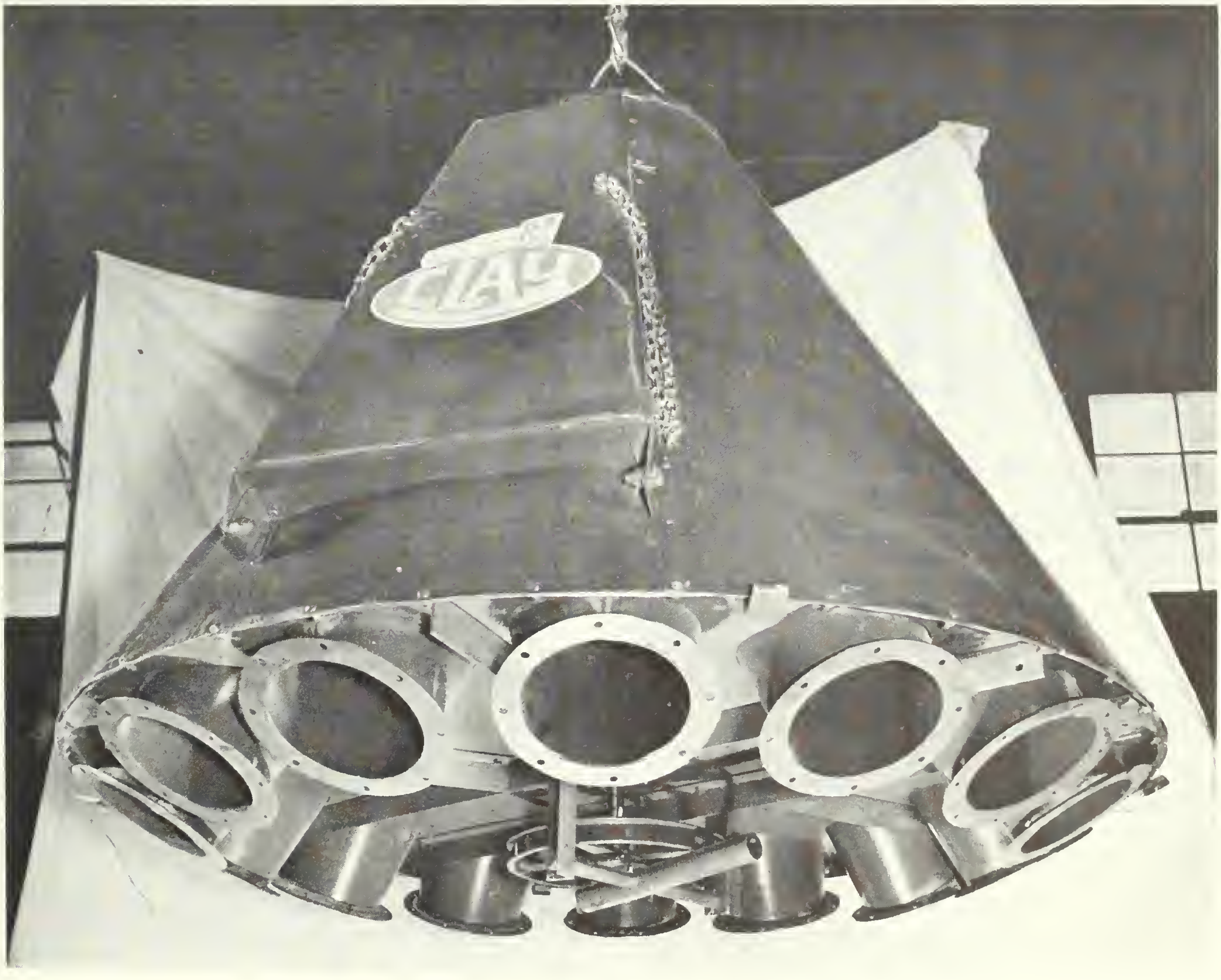


Figure 2.3.12 Large distributor. Courtesy: Clay Equipment Corp.

A guide to selecting bucket elevators for various required capacities and the associated power requirements is given in Table 2.3.16 and Table 2.3.17.

TABLE 2.3.16 Approximate Power and Capacity for Shelled Grain Belt-Type Bucket Elevators

mm	Bucket Spacing mm	Belt Speed m/s	Capacity m^3/hr	Power W/m
76 x 51	203		2	18.4
	102		4	
102 x 76	203		7	24.5
	152	1.38	11	30.6
152 x 102	108	1.38	18 - 19	48.9
	108	1.71	25	61.2
178 x 127	203		32	73.4
	152	1.71	42	80.7
229 x 127	178	1.35	56	122.3
	152	1.53	63	122.3
229 x 152	305	1.96	53	152.9
	152	1.96	106	305.8
in	in.	ft/min	bu/hr	hp/10 ft
3 x 2	8		50	0.075
	4		100	
4 x 3	8		200	0.10
	6	270	300	0.125
6 x 4	4½	270	500 - 550	0.20
	4½	335	700	0.25
7 x 5	8		900	0.30
	6	335	1200	0.33
9 x 5	7	265	1600	0.5
	6	300	1800	0.5
9 x 6	12	385	1500	0.625
	6	385	3000	1.25

Source: Purdue University, A.E. Data Sheet 8.1

TABLE 2.3.17 Motor Size Recommended For Bucket Elevators

Elevator Height m	Elevator Capacity m^3/h 106	123	141	176	211
	**Motor Size kW				
6	2.2	3.7	3.7	3.7	5.6
9	3.7	3.7	5.6	5.6	5.6
12	3.7	5.6	5.6	7.5	7.5
15	5.6	5.6	7.5	7.5	11.2
18	5.6	7.5	7.5	11.2	11.2
21	7.5	7.5	11.2	11.2	14.9
24	7.5	11.2	11.2	11.2	14.9
27	11.2	11.2	11.2	14.9	14.9
30	11.2	11.2	11.2	14.9	18.6
33	11.2	11.2	14.9	18.6	18.6
*37	11.2	14.9	14.9	18.6	22.4
40	11.2	14.9	14.9	18.6	22.4
43	14.9	14.9	18.6	22.4	22.4
46	14.9	14.9	18.6	22.4	29.8
	Elevator Capacity bu/hr 3000	3500	4000	5000	6000
ft	**Motor Size hp				
20	3	5	5	5	7½
30	5	5	7½	7½	7½
40	5	7½	7½	10	10
50	7½	7½	10	10	15
60	7½	10	10	15	15
70	10	10	15	15	20
80	10	15	15	15	20
90	15	15	15	20	20
100	15	15	15	20	25
110	15	15	20	25	25
*120	15	20	20	25	30
130	15	20	20	25	30
140	20	20	25	30	30
150	20	20	25	30	40

*Above 37 m (120 ft) use optional 14 gauge legging.

**Power requirements may vary with type and condition of grain or material as well as method of inlet.

Adapted from Royal Industries, Hutchinson Division.

2.3.6.5 Example Problem

A bucket elevator is required to elevate wheat weighing 769 kg/m^3 to a height of 24.4m at the rate of 15.34 kg/s. The power requirement then is

$$P = \frac{1.2\,(15.34)\,(9.81)\,(24.4)}{.85}$$

$$= 5244 \text{ W or } 7.04 \text{ hp},$$

therefore choose a 5.2 kW (7½ hp) drive motor.

Check belt speed

Assume the buckets are 229 mm x 152 mm (9 x 6 in.) at a spacing of 178 mm (7 in.). For a 90% fill the usable capacity from Table 2.3.18 is .00315 m^3 (192 $in.^3$) then

$$V = \frac{15.34\,(.178)}{.00315\,(769)}$$

$$= 1.13 \text{ m/s}$$

or 221 fpm, which is within the range noted in Table 2.3.16.

Several manufacturers are employing higher than normal belt speeds in round tube elevator legs to improve the capacity/cost ratio. This is primarily directed at the smaller elevators that are adequate for most grain farms and feed lots in Canada (6).

2.3.6.6 Bucket Elevator Data

Specifications of useable capacity of individual buckets of nominal dimensions along with dimensional details and weights are summarized in Table 2.3.18. The spacing of individual cups and the speed of rotation for various head pulley sizes on centrifugal discharge elevators is given in Table 2.3.19 and Table 2.3.20. Belt selection and specifications are provided in Table 2.3.21 to 2.3.23 inclusive.

With the arrangement of storage bins worked out in relation to the bucket elevator it is possible to determine the total height of the bucket elevator. This includes the boot, the hopper, the distributor at the top and the head

TABLE 2.3.18 Typical Elevator Cup Specifications

Nominal Size (in. x in.)	Actual Size in Inches (See Drawing Below for Key to Dimensions): Length	Projection	Depth	Standard Punching (in.): Top of Back to Center of Bolt Holes	Center to Center Bolt Holes	Number of Bolt Holes	Diameter of Bolt Holes	Diameter of Bolts	Capacity and Weight: Usable Cu in. Capacity 90% Full	Weight in Pounds Each
	A	B	C	D	E					
3x3	3	3⅛	2¾	⅞	1¾	2	5/16	¼	15	.45
4x3	4	3⅛	2¾	⅞	2⅛	2	5/16	¼	21	.55
5x3	5	3⅛	2¾	⅞	3 1/16	2	5/16	¼	25	.65
5x4	5	4 5/16	3¾	1¼	3 1/16	2	5/16	¼	46	1.25
6x4	6	4 5/16	3¾	1¼	4⅜	2	5/16	¼	56	1.40
7x4	7	4 5/16	3¾	1¼	2 11/16	3	5/16	¼	65	1.55
8x4	8	4 5/16	3¾	1¼	3 1/16	3	5/16	¼	74	1.70
9x4	9	4 5/16	3¾	1¼	3⅝	3	5/16	¼	84	1.85
10x4	10	4 5/16	3¾	1¼	4⅛	3	5/16	¼	93	2.00
11x4	11	4 5/16	3¾	1¼	3	4	5/16	¼	102	2.15
12x4	12	4 5/16	3¾	1¼	3⅜	4	5/16	¼	111	2.30
6x5	6	5⅜	4¾	1¾	4⅜	2	5/16	¼	86	1.90
7x5	7	5⅜	4¾	1¾	2 11/16	3	5/16	¼	102	2.10
8x5	8	5⅜	4¾	1¾	3 1/16	3	5/16	¼	116	2.30
9x5	9	5⅜	4¾	1¾	3⅝	3	5/16	¼	130	2.50
10x5	10	5⅜	4¾	1¾	4⅛	3	5/16	¼	156	2.75
11x5	11	5⅜	4¾	1¾	3	4	5/16	¼	159	2.95
12x5	12	5⅜	4¾	1¾	3⅜	4	5/16	¼	174	3.15
13x5	13	5⅜	4¾	1¾	3⅜	4	5/16	¼	188	3.35
14x5	14	5⅜	4¾	1¾	3	5	5/16	¼	202	3.50
15x5	15	5⅜	4¾	1¾	3¼	5	5/16	¼	217	3.75
16x5	16	5⅜	4¾	1¾	2⅞	6	5/16	¼	231	4.00
8x6	8	6½	5¾	2	3 1/16	3	5/16	¼	171	3.00
9x6	9	6½	5¾	2	3⅝	3	5/16	¼	192	3.25
10x6	10	6½	5¾	2	4⅛	3	5/16	¼	213	3.60
11x6	11	6½	5¾	2	3	4	5/16	¼	235	3.85
12x6	12	6½	5¾	2	3⅜	4	5/16	¼	255	4.15
13x6	13	6½	5¾	2	3⅜	4	5/16	¼	277	4.45
14x6	14	6½	5¾	2	3	5	5/16	¼	299	4.75
15x6	15	6½	5¾	2	3¼	5	5/16	¼	319	5.50
10x7	10	7⅜	6¾	2	4⅛	3	11/32	5/16	282	4.80
11x7	11	7⅜	6¾	2	3	4	11/32	5/16	309	5.10
12x7	12	7⅜	6¾	2	3⅜	4	11/3	5/16	337	5.45
13x7	13	7⅜	6¾	2	3⅜	4	11/32	5/16	365	5.80

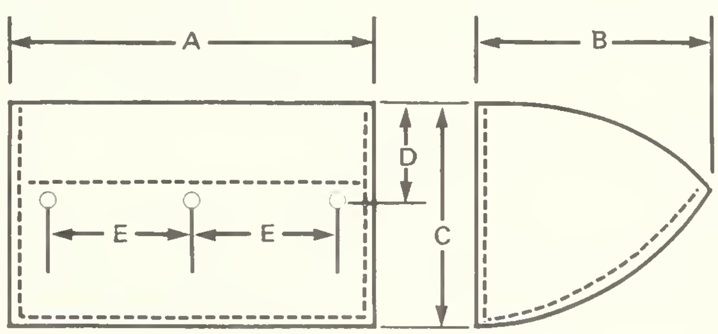


TABLE 2.3.19 Minimum Spacing for Elevator Cups

Projection	Allowable Min. Spacing		Typical Spacing
	Solid	Vented	Solid
mm	mm	mm	mm
80	90	130	115
100	115	170	150
130	150	230	180
150	180	270	200
180	230	340	230
in.	in.	in.	in.
3	3.5	5.25	4.5
4	4.5	6.75	6.0
5	6.0	9.0	7.0
6	7.0	10.5	8.0
7	9.0	13.5	9.0

TABLE 2.3.20 Suggested Elevator Head Pulley Speeds

Head Pulley Diam.	Min-Max rpm for Cups	
mm	Solid	Vented
300	69-97	58-87
410	60-84	42-72
460	56-79	44-66
510	54-76	42-63
610	50-70	38-54
760	45-63	35-51
910	41-57	33-49
1070	39-55	31-46
in.		
12	69-97	58-87
16	60-84	42-72
18	56-79	44-66
20	54-76	42-63
24	50-70	38-54
30	45-63	35-51
36	41-57	33-49
42	39-55	31-46

TABLE 2.3.21 Minimum Plies for Various Cup Projections

Material	Bucket Projection in.						Belt Fabric oz*
	3	4	5	6	7	8	
Free flowing grain	4	4	5	5	6	6	28 or 32
Feed	4	4	4	5	5	6	

*Belt fabric or duck is graded by the weight of a strip 36 in. wide by 40 in. long

TABLE 2.3.22 Maximum Plies For Standard Pulley Diameters

Head Pulley mm	Max. Plies	Min. Foot Pulley mm
300	3	300
410	4	360
510	5	380
610	6	460
710	7	530
760	8	560
910	9	660
in.		in.
12	3	12
16	4	14
20	5	15
24	6	18
28	7	21
30	8	22
36	9	26

clearance of the top drive pulley. Based on the horizontal distance from the storage bin fill point to the elevator and the slope of spouting required for the material to be handled (see 7.1.4) and using Figure 2.3.5 the effective elevator height can be determined.

Based on 1975 prices the cost of a basic leg can vary from $2100 for small capacity 9 m (30 ft) leg to $4400 for a 105 m^3/hr (3000 bu/hr) capacity 24 m (80 ft) leg. To this basic price must be added the cost of the power unit, distributor, spouting, pit and pit conveyor (7, 9).

The width of the belt should be the bucket width plus 25 mm (1 in.). The pulley width should be belt width plus 25 mm (1 in.). Belts must have sufficient tensile strength and be thick enough to prevent the bucket bolts from tearing out of the belt.

When the basic plan of the feed handling system has been determined and the size of unit established, the final step is to prepare a set of specifications that can be supplied to the manufacturers of the equipment. Table 2.3.24 itemizes the information necessary for the manufacturer to supply the equipment suited to the specific farm requirements.

2.3.6.7 **Installation Considerations**

The Boot

The boot or bottom pulley housing of an elevator leg should be set on a firm and level foundation and maintained free of water. Inlet hoppers can be placed on either the down side, up side or both sides of the boot. Most free-flowing materials including whole grains are best fed into the up side. An additional 20% should be added to the theoretical power requirement for this situation, as shown in the example problem. If the material is fed in on the down side an additional 50% should be added to the theoretical power requirements.

TABLE 2.3.23 Weight and Strength of Conveyor Belt

Duck Weight oz*	Weight lb/in. width/ft	Max. Tensile Strength lb/ply/in.	Working Tensile Strength 16/ply/in.
28	0.021	280	28
32	0.024	300	30
35-36	0.026	325	36
42	0.029	375	42

*Belt weight is based on 36 in. wide strip by 40 in. long

TABLE 2.3.24 Required Engineering Information - Elevator Belt

Specifications required when ordering elevator belts
Include sketch of elevator with principal dimensions.

Items Essential for Recommendation			These items, if Available, Assist in Recommendation		
Type of Elevator					
Centrifugal Discharge			Angle of incline from horizontal		
Continuous			Loads from		
Vertical	inclined		Discharges to		
Belt width	length		Loading of buckets		
Pulley Centers			Fly feed	digging in boot	
Vertical Lift			Boot pulley: type		
Loading Rate			Solid	slatted	vane
TPH	max	avg	Take-up, type		
Bu per hr	max	avg	Screw	gravity	
Material Handled			Movement	weight	
Wt per cu ft	max size		Type of splice		
Percent fines			Fasteners	lap joint	
Wet or dry	temperature		Butt-strap joint	vulcanized	
Belt Speed			Other		
Buckets			Motor hp	rpm	
Size and style			Type	Drive Pulley rpm	
Number of rows	capacity		Elevator is enclosed		open
Drive			Previous belt construction		
Lagged	bare				
Wrap			Final tonnage		
Pulley Diameters			Cause of failure		
Head	boot				

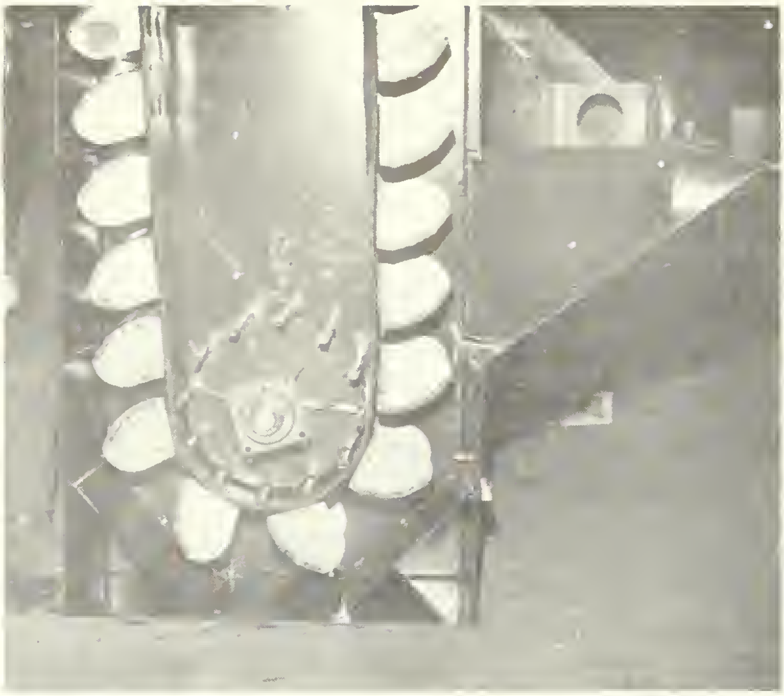


Figure 2.3.13 Elevator boot and inspection section. Courtesy: Clay Equipment Corp.

Feeds or light materials that tend to dust are best fed in on the down leg side for better filling of the cups or buckets.

Inspection Door

An inspection door at a convenient height is required; to insert the belt and cups during erection, to splice the belt and to check the condition of the cups during operation.

Plumbing and Guying

Bucket elevators must be well braced to resist wind and mechanical loads. Guy wires (9.5 mm) (3/8 in.) stranded cable are required in 4 directions and sloped at an angle of about 45°. For discharge heights over 9 m (30 ft) additional guy wires are required. Guys should be attached to the vertical leg at 6 m (20 ft) intervals for legs greater than 12 m (40 ft) in height. The maximum unsupported height should not exceed 9 m (30 ft). Guy wires must be firmly anchored to concrete deadmen with 12.7 m (½ in.) diameter galvanized eye bolts 0.9 m (3 ft) by 1.8 m (6 ft) by 1.8 m (6 ft) high.

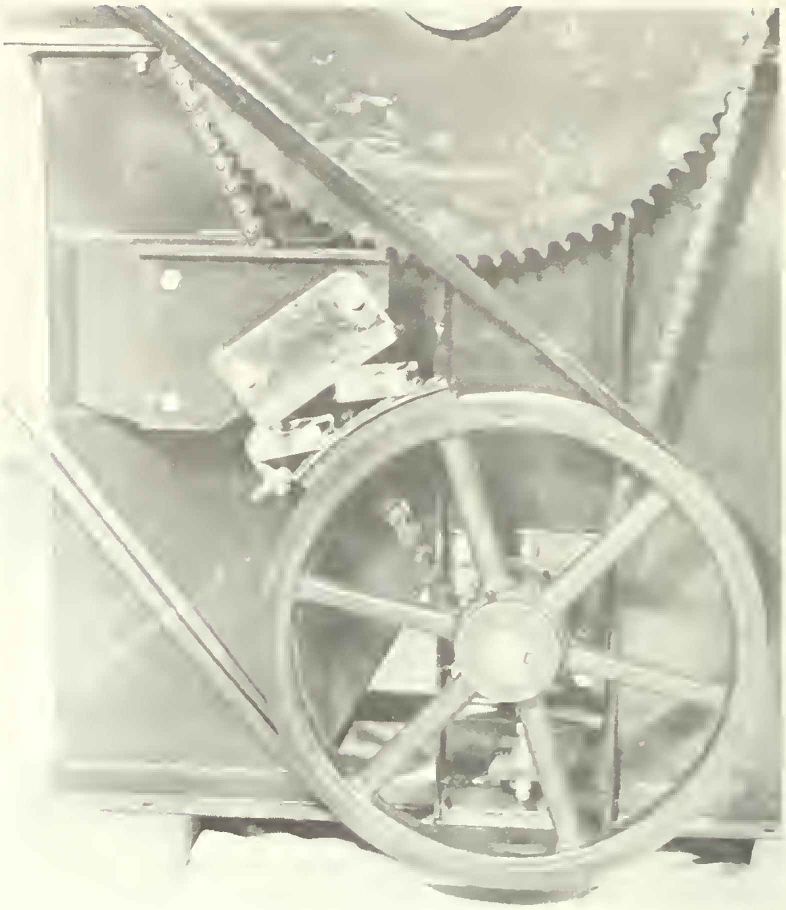


Figure 2.3.14 Anti-reversing brake. Courtesy: Clay Equipment Corp.

The use of 2 transits is recommended to aid in plumbing the elevator as it is erected. The transits should be placed at least 30.5 m (100 ft) away from the elevator and at 90° to each other and the elevator brought into plumb with adjustable turn buckles on the guy wires (7).

TABLE 2.3.25 Recommended Types of Conveyors and Elevators For Some Agricultural Products.

Material	Avg Density kg/m^3	Recommended* Conveyors	Recommended* Elevators	Comment
Bone meal	55-60	a,b,c,d,e	g,h,c	
Bran	16-20	a,b,c,d,e	g,h	Sometimes sticky
Brewers grains	55	c,e	g,h	
Corn, shelled	45	a,c,e	g,h,e	
Flax	45	a,b,c,d,e	g,h,c	Free flowing
Soybean meal	30	a,b,c,e	g,c	Explosive dust
Wheat	48	a,c,d,e	g,c	Keep clean

*Explanation of letter symbols

a - belt. b - flight. c - continuous flow. d - pneumatic. e - auger. f - drag chain. g - belt and bucket. h - chain and bucket

2.3.7 REFERENCES

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